AN
EPITOME
OF A
Courſe of Lectures
ON
NATURAL AND EXPERIMENTAL
PHILOSOPHY:

AS THEY ARE DELIVERED BY

JOHN BANKS.

BY THE WORD OF THE LORD WERE THE HEAVENS MADE; AND ALL THE HOST OF THEM BY THE BREATH OF HIS MOUTH. PS. XXXIII, 6.

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PREFACE.

THIS Epitome is chiefly deſigned for the uſe of thoſe who have attended my courſe of experiments; to ſuch, I am perſuaded, it will be found of ſervice, by recalling ideas which had ſlipt the memory; and the want of plates, it is preſumed, will be abundantly compenſated by the apparatus; and to thoſe who have not yet had the opportunity, it may, in ſome meaſure, convey the firſt principles of the ſciences, provided they will be content with naked aſſertions, without either mathematical demonſtration, or experimental proof.

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AN EPITOME OF A COURSE of LECTURES.

INTRODUCTION.

THIS courſe is intended to explain, in the moſt eaſy and familiar manner, the general properties and laws of matter; and to ſet before the inquiſitive mind, the cauſes of the moſt material phænomena which we obſerve amongſt natural bodies; at leaſt, ſo far as diſcovered; for though we muſt confeſs that the works of infinite wiſdom can never be fully comprehended by the faculties of man, yet how far reaſon, when aſſiſted with inſtruments, may attain, ſeems to us indeterminable; thus the philoſophers of the preſent age, tho' ſtill wholly ignorant of the true cauſes of many of the moſt common phænomena, have nevertheleſs, by diligent enquiries and experiments, gained the knowledge of many equally unknown to our forefathers, and by them, perhaps deemed incomprehenſible. And there is no doubt but in future ages, ſcience will continue its progreſſion; for it ſeems providentially appointed, as ſome way neceſſary for the carrying on, or well being of ſociety, that the ſciences ſhould be gradually improving. Yet ſtill it muſt be acknowledged, that many things are known, which reaſon could never have led us to the knowledge of: but whilſt man has been diligently ſeeking after one thing, he has accidentally, or rather providentially, hit upon, or diſcovered another, of greater importance, and of more extenſive utility to mankind.

As to the uſe of philoſophy, it muſt be confeſſed to be almoſt unlimited, and may be recommended to people of all ranks. For many things appear to be, what in reality they are not. Thus to the eye, unaſſiſted by philoſophy, the Sun appears to be a flat ſhining plate, the ſtars to be ſmall lucid points, like diamonds, and all at equal diſtances from us; and ſeem to revolve round the Earth in twenty-four hours; while the Earth ſeems to be fixed, and to be by much the largeſt body in the univerſe. But a competent knowledge in philoſophy will ſtrip things of the diſguiſe and falſe colours under which they appear; or rather inſtead, as is too commonly ſuppoſed, of contradicting the plain and poſitive proof of the ſenſes, evince, to the moſt unanſwerable demonſtration, the impoſſibility of their appearing otherwiſe

therwiſe; and from thoſe very appearances deduce the moſt convincing arguments to ſupport its own aſſertions; thus will it furniſh the mind with more juſt and ſublime ideas, by removing the errors of prejudice, received by falſe education, cuſtom, or the authority of men.

PHILOSOPHY alſo, as it is concerned in the invention and adjuſtment of machines, is of univerſal utility to mankind; to it we owe the conſtruction of ſhips, ſteam-engines, water-engines, pumps, mills, clocks, watches, dials, teleſcopes, cranes, jacks, the organ, harpſichord, and every other kind of inſtrument, machine, or engine, however complicated, or for whatever purpoſes they are appointed.

IN teaching philoſophy as a ſcience, it is neceſſary to begin with the moſt ſimple and known properties of bodies; and thence to proceed, by inferring one truth from another, till we arrive at the moſt abſtruſe parts; always uſing experiments where the nature of the thing will admit them, except that which is aſſerted be ſufficiently plain without. And though the experiments afford the higheſt degree of entertainment to the rational mind; yet ſo much the more inſtruction will they convey, as this regular proceſs is more attended to, and better imprinted on the memory.

LECTURE

LECTURE I.

Of the general Properties of Matter.

THIS Lecture is intended to explain the general properties of matter, the different kinds of attraction, and from thence to deduce the principles of ſeveral uſeful arts. We have four rules whereby we ſhould be guided in our philoſophical enquiries: the firſt is,

That more cauſes for natural effects are not to be admitted than are both true and ſufficient to explain the phænomena.

THIS agrees with reaſon, and revelation; for it is certain that God has made nothing in vain; which would evidently be the caſe, if two cauſes were admitted where one would ſerve.

THE ſecond is, *That for natural effects of the ſame kind, the ſame cauſes are to be aſſigned as far as can be done.*

THAT is, we are to aſſign the ſame cauſe for the falling of ſtones in America, Africa, &c. as in Europe; the ſame cauſe for reſpiration in man and beaſt; and that light in all kinds of bodies is produced by the very ſame cauſe.

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The third rule is, *That the qualities of natural bodies, which cannot be increaſed or diminiſhed, and agree to all bodies on which experiments can be made, are to be reckoned, as the qualities of all bodies whatſoever.*

Thus, becauſe extenſion, ſolidity, diviſibility, &c. are found in all bodies that we know, we may juſtly conclude that they belong to all bodies whatſoever.

The fourth rule is, *That in experimental philoſophy, propoſitions collected from the phænomena, by induction, are to be deemed, notwithſtanding contrary hypotheſes, either exactly or very nearly true, till other phænomena occur, by which they may be rendered either more accurate, or liable to exception.*

All bodies whatever are found to have the following common properties, *viz.*

Extenſion,
Solidity,
Diviſibility,
Mobility,
Vis Inertiæ,
Attraction, and Repulſion.

EXTENSION, is a property which belongs to all matter in general; for it is certain no body can exiſt, but it muſt take up ſome part of ſpace.

SOLIDITY, is that property which a body hath of excluding all others, from the place it poſſeſſes.

DIVISIBILITY, is a property whereby bodies are capable of having their parts ſeparated *ad infinitum*. * That this property exceeds the utmoſt bounds of our imagination, is a mathematical truth, and may be demonſtrated different ways.

MOBILITY, is that property which bodies have of being moveable.

The *VIS INERTIÆ*, or inactivity, of matter, is that property whereby bodies reſiſt the action of other bodies, tending to generate or deſtroy motion in them.

ATTRACTION, is a property whereby bodies mutually tend towards each other; if the bodies be of unequal magnitude, in the greater, it is called attraction, and in the leſſer, gravitation.

REPULSION, ſeems to be a property belonging to the ſmalleſt particles of matter; thus we ſee the particles of water, ſeparated by the action of fire, repel each other; and the particles of any kind of hard matter, being ſet at liberty by ſome chymical proceſs, conſtitute a perfectly elaſtic air.

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* If it is true, as generally maintained, that one particle is capable of being divided into an infinite number, which number cannot be increaſed; may not another particle alſo be divided into an infinite number, which number cannot be increaſed; and in like manner a third, &c. and if theſe cannot be added, will it not follow, that there may exiſt many infinite numbers?

But if the whole material creation, however extenſive, was divided into particles infinitely ſmall, would the number be more than infinite?

THE attraction of gravitation takes place only in large bodies, ſuch as the Sun, Earth, and planets, and is a property whereby all ſmaller bodies within the ſphere of their attraction, tend towards their centres. The attracting effluvium or energy is found to decreaſe as the ſquares of the diſtances increaſe; that is, if a body at the diſtance of 10,000 miles from the Earth tend towards it with a certain force; at the diſtance of 20,000 miles, it would tend towards it with only one fourth part of that force; at the diſtance of 30,000, with only one ninth part thereof, &c.

THE planets are all retained in their orbits by the attraction of the Sun; and by their motions, the above law is fully confirmed; for as the ſquare of the diſtance of Venus from the Sun, is to the diſtance that Mercury falls from a tangent to his orbit in one hour; ſo is the ſquare of the diſtance of Mercury from the Sun, to the diſtance that Venus falls from a tangent to her orbit, in the ſame time; *and ſo of the reſt.*

THE power which unites the original particles is called the attraction of coheſion, and is mutual between them, or they are attracted and attract each other. This power ſeems to act only in contact, or at imperceptible diſtances in all ſolid bodies. The exiſtence of this power is proved by two leaden balls, having their ſurfaces pared very clean, and preſſed together with a gentle twiſt, after which they will require 40, 60, or 100 pounds weight to pull them aſunder, according as more or leſs of the ſurfaces are in contact; for this power ſeems to act nearly in proportion to the quantities of contiguous ſurfaces. This is the natural cement by which the parts of ſolid bodies are bound together, and by which they are kept from crumbling to their original duſt. Hard bodies, which cannot by preſſure be brought into intimate contact like the leaden balls, require ſome kind of matter to be put between them, in order to make them cohere; ſo if flint, glaſs, &c. reduced to impalpable powder, and mixed with ſome viſcid fluid, be applied between two bodies, whoſe ſurfaces are clean, when dry it will make them cohere very firmly. Hence we ſee the reaſon that in poliſhed ſurfaces, a little damp is ſufficient to make them cohere; if a little oil or tallow be uſed, the coheſion is much ſtronger, *as is ſhewn by experiment.*

FROM this principle we have alſo the nature of ſoldering, gluing, foliating glaſs, ſilvering and gilding metals, &c. *as explained in the lecture.*

THE attraction of coheſion is different between the particles of different bodies; thus, water put into clean glaſs, china, &c. is ſeen to riſe all round by the ſide of the veſſel; but if quickſilver be uſed, it will ſtand loweſt at the ſides; from whence it appears, that the power of attraction is greater between the glaſs and water, than among the particles of water themſelves; and that it is greater among the particles of quickſilver, than between the glaſs and quickſilver. In this ſimple cauſe, divine wiſdom is abundantly manifeſt; for, by it we have numbers of the moſt extraordinary effects produced.

It is owing to this, that water riſes above the common level in the capillary tube; alſo the action of the capillary ſyphon, and filtre, depends on the ſame principle; for the capillary ſyphon, being a ſmall bended tube of glaſs, by attraction raiſes water up one leg, carries it over the bended part, and down the other, where it falls, by its own weight, drop by drop. The filtre being made of yarn, felt, cloth, &c. the filaments act like ſo many ſyphons, and carry a fluid off in the ſame manner, but much faſter. From hence we have the reaſon of fluids riſing in heaps of ſand, aſhes, ſugar, &c. of tallow riſing in the wicks of candles; of water being drawn up the ſpunge; of ink riſing in the pen, and alſo of its being drawn out again in writing. From hence we alſo account for the riſing of ſap in trees and plants; for upon proper examination, it is found, that the bodies of trees are compoſed of an infinite number of capillary tubes, of different magnitudes; the largeſt ſeem by various experiments, to be appointed for the circulation of air; and the ſmaller for attracting the juices of the earth, and raiſing them to the top and utmoſt parts of the branches; for it may be obſerved, that the ſmaller the bore of the tube, the higher a fluid will riſe, *as is ſhewn in the experiment.*

From hence we have alſo the cauſe of ſeveral chymical proceſſes.

Solution.

For if a ſolid and a fluid be put together, provided the power of attraction between the particles of the fluid and the particles of the ſolid be ſtronger than between the particles of the ſolid themſelves, every particle of the fluid will then attract a particle of the ſolid, or ſo many as it can ſuſtain, and then, the whole menſtruum being ſaturated therewith, the ſolution will ceaſe; as is evident by putting ſilver, copper, braſs, iron, &c. in aqua-fortis or ſpirit of nitre; by putting ſalt or ſugar in water; and by water itſelf being diſſolved and diffuſed through every part of the atmoſphere, by the ſtrong attraction of the particles of air.

Precipitation.

Any matter, thus diſſolved and ſuſpended, is precipitated by the very ſame cauſe; for, if to any kind of ſolution, ſome body be added, ſo that there be a ſtronger attraction between the new added matter and the menſtruum, than between the menſtruum and the diſſolved body, the new matter will then take place of the old, and let it fall to the bottom.

To a ſolution of epſom ſalt in water, add a ſolution of alkaline ſalt; the baſis of the epſom ſalt will be precipitated in white flakes, which is the *magneſia alba*.

Epsom ſalt is compoſed of magneſia and the acid of vitriol.

A more powerful attraction takes place between the acid and alkali, than between the acid and magneſia; hence the magneſia is thrown down, and between the acid and alkali a new ſalt is formed. (Vitriolated tartar.)

Lead is diſcovered in water or white wine, by adding liver of ſulphur diſſolved in lime water: the mixture appears red, and in time precipitates.

Copper in water may be diſcovered, by adding volatile alkali, which turns it blue.

If iron is contained in water, a decoction of galls will turn it black, or it may be precipitated by phlogiſticated alkali; to which if we add marine acid, a beautiful berlin blue is formed.

Water containing ſelenites, allum, ſal-amoniac, or calcareous earth, will appear milky by adding a ſolution of alkali.

New ſyrup of violets added to water which contains an acid, will turn it red, but if it contains an alkali, green.

Fermentation depends upon the ſame power; for if two fluids be put together, provided there be a different power of attraction between their particles, they will thereby be thrown into a ſtrong agitation and commotion amongſt themſelves, and will be ſo incorporated with each other, that they will ſeem to have changed their properties, and acquired new ones.

From this difference of the degrees of attraction between different bodies, we have perhaps the moſt rational way of accounting for heat, exploſions, earthquakes, volcanos, &c.

If aqua-fortis be poured upon iron-filings, a very conſiderable degree of heat is produced.

Also, if three parts of nitre, two of ſalt of tartar, and one of ſulphur, be pounded and mixed together (which mixture is called *pulvis fulminans*) and a ſmall quantity of it heated upon an iron plate, as ſoon as it begins to melt, and the particles of the different bodies come in contact, the nitre is in an inſtant converted into air.

Also, if equal parts of ſulphur and iron-filings be made into a paſte with water, and put under ground, they will, in eight or ten hours time, take fire, and blow up the ground about them, venting flames and ſmoke like a volcano. And as it is well known that the earth abounds with great quantities of ſulphur, iron ore, &c. it is probable theſe may be brought together, either by ſubterraneous waters, or other cauſes unknown to us, and by the violence of their fermentation, at length break forth in flames, as in burning mountains; or when confined deep in the bowels of the earth, if the compactneſs of the ſuperincumbent maſs refuſes to give way for an eruption, the effort for enlargement is then made on that quarter, which, by caverns, or the more yielding and looſe contexture of its parts, affords the leaſt reſiſtance; hence may ariſe that wandering convulſive motion, which is denominated an earthquake. *

The attraction of *magnetiſm* is peculiar to the loadſtone and iron, as there is no other body but iron that it can be communicated to.

Every loadſtone has two poles, one called the north, and the other the ſouth pole. One of theſe poles attracts, and the other repels iron.

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* Some have conſidered electricity as a principal agent in theſe awful phænomena.

This virtue may be communicated to iron different ways, and thereby artificial magnets may be made to anſwer all the ends of a natural one.

If we take four or five ſteel bars, ſix inches long, half an inch broad, and about an eighth of an inch thick, well poliſhed and hardened, if they be laid end to end, and the magnet drawn over them ſeveral times, they will become ſtrongly impregnated with the virtue. Theſe properly fitted up in a caſe, will make a good artificial magnet; but perhaps it may be better in ſome caſes to have the bars bent in a particular manner, *as is ſhewn in the experiment.*

This virtue may alſo be communicated to a piece of poliſhed ſteel, by placing it in the magnetic meridian, and rubbing it always one way with a burniſher.

Iron bars, by ſtanding long in one poſition, acquire the magnetic virtue.

If a magnet be made red hot, or become ruſty, it loſes much of its virtue.

It is generally ſuppoſed that the effluvia, coming out at one pole, return in curves of various directions, and enter in at the other; and indeed we have ſeveral experiments which countenance ſuch an hypotheſis.

If a magnetic needle be ſuſpended upon a point, in England it will now make an angle, with the meridian, of about 22 degrees; the north end being towards the weſt, and the ſouth end towards the eaſt, which is called the variation of the needle.

In 1580, it had one point eaſt variation; in 1657, it had no variation.

When a needle is well made, and ſuſpended like a ſcale beam, in moſt places it dips below the plane of the horizon.

In 1775, in a voyage, to Madras, the variation and dip were as below.

Lattitude.			Longitude.			Variation.			Dip.		
	°	'		°	'		°	'		°	'
N.	49	0	W.	6	0	W.	18	42	N.	73	4
	33	30		15	30		19	16		65	1
	9	15		16	0		12	50		38	6
	1	10		16	16		12	47		24	2
S.	7	10		23	30		6	30		11	0
	14	6		26	28		4	20	S.	2	2
	22	8		31	0	E.	0	44		15	3
	34	25		18	21	W.	3	18		35	6
	34	49	E.	36	26		27	30		58	4
	28	20		78	10		12	49		57	7
	5	26		81	17		0	8		30	3
N.	5	19		88	13		0	53		8	0
	9	28		85	10		0	53	N.	0	5
	10	55		84	55		0	53	S.	0	33
	14	17		81	23		1	22		8	5

LECTURES II. & III.

Of Pneumatics.

PNEUMATICS is that part of philoſophy which treats of the nature and properties of the air.

THE particles of air are extremely ſmall, ſo that they evade the ſight, though aſſiſted with the beſt glaſſes. It is moſt likely that theſe particles are round, and that a repelling power takes place between them, for the air is found to be an elaſtic fluid.

THE whole body of air in which we breathe, and which ſurrounds the globe of the Earth, is called the atmoſphere.

THE air, being elaſtic, is at every different altitude of a different denſity; that is, it is moſt denſe upon the ſurface of the Earth, and the higher we aſcend, it becomes more rare or thin; except that which is near the Earth be ſometimes rarified by the heat reflected from its ſurface.

THE altitude of the atmoſphere is not exactly known; it extends about 45 miles above the Earth's ſurface before it be too thin to refract a ray of light;

if it was every where of the ſame denſity with that near the Earth, its altitude would be about five miles and a quarter.

That the air is a body, is evident by its excluding other bodies from the place it poſſeſſes; for if a glaſs be inverted and ſunk in water, the water will not riſe in it, as is evident by a lighted candle continuing to burn in it, though under water. The diving bell depends on this property of the air; for if a large veſſel be made heavy enough to ſink with the open end downward, a perſon may deſcend in it to a conſiderable depth, and the water will be kept from riſing by the ſpring of the air; yet the air being elaſtic, and therefore capable of being compreſſed, as the bell deſcends the water will gradually riſe; and when it comes to the depth of 33 feet, half its capacity will be filled with water; but it may be kept from riſing, or driven out after it is riſen, by ſending down caſks filled with freſh air, which may be taken in at the bottom of the bell, while that corrupted by breathing may be diſcharged at the top, by a cock for that purpoſe.

As the air is a body, it has alſo weight, and gravitates towards the Earth like other bodies, in proportion to its quantity of matter.

The weight of the air is evident from a number of experiments.

1. If the hand be laid upon a receiver, open at the top, and the air pumped from under it, the weight of the external air will be felt upon the back of the hand, and will preſs it cloſe down to the receiver.

2. If a glaſs bubble, containing a wine quart, be emptied of its air, and then nicely balanced, as ſoon as the air re-enters, it will preponderate, and will be about 17 grains heavier than when empty.

3. If two braſs hemiſpheres be exhauſted, and the air ſhut out by a cock, they will require a force of about 15 pounds to every ſquare inch to pull them aſunder.

4. If a glaſs bubble, with its neck immerſed in water, be exhauſted of its air, when the air re-enters, it will preſs upon the ſurface of the water, and force it up into the bubble.

5. Let a tall receiver be ſet upon a moveable plate, to which is ſcrewed a pipe with a cock, and exhauſt it, then placing the end of the pipe in water, and opening the cock, the preſſure of the external air will be ſeen forcing the water into the receiver with great velocity.

6. Take a ſtick of oak, hazel, &c. with a hoop round one end of it to hold quickſilver, and with

wet leathers fix it in the top of an open receiver, ſo as to be air-tight, when the receiver is exhauſted, the weight of the air preſſing upon the mercury in the hoop, will force it through the pores of the wood.

7. IF a bladder be faſt tied over the top of an open receiver, as ſoon as the air is ſufficiently rarified below, the weight of the column above, will break the bladder with a conſiderable report.

8. IF a piece of hazel, having its ends cut very ſmooth, be fixed in the neck of an open receiver, and the lower end immerſed in water, upon exhauſting, the outward air, by its weight, will ruſh through the pores of the wood, and riſe through the water in fine ſtreams.

9. IF a ſquare glaſs bottle be exhauſted, it will be broken into ſmall pieces by the preſſure of the circumambient air.

10. A PIECE of plain glaſs laid over an open receiver, will be broken in the ſame manner.

11. IF a barometer be placed under a tall receiver, as the air is exhauſted, the mercury will fall; when the air re-enters, it will riſe again. From hence it is evident, that the mercury is ſupported in the tube by the weight of the air; and therefore, in fine dry

weather, when the atmoſphere is heavieſt, it will ſtand higheſt; on the contrary, in rainy weather, when it is lighteſt, the quickſilver will be loweſt.

From this experiment it is found, that the air will ſupport a column of mercury to the altitude of 29½ inches, at a mean. The diameter of the tube makes no difference, the reaſon of which will appear evident, when we come to explain the laws of *hydroſtatics*. For as the weight of a column of mercury, of any given diameter and altitude, is known, the weight of a column of air, of the ſame diameter, is alſo known, and is at a mean about 14lb. upon every ſquare inch; and upon every ſquare foot 18 cwt. or near one ton. Now, if we ſuppoſe the ſurface of a middle-ſized man to be 15 feet, it will follow that he will ſuſtain a preſſure of 13½ tons; which, were it not balanced be the ſpring of internal air, could not be ſupported.

But the particles of air being extremely ſmall, enter into every part of our bodies, and by their elaſticity balance the preſſure of the ſurrounding atmoſphere.

12. This is evident by placing the hand upon an open receiver; for as ſoon as the preſſure is deſtroyed, the air in the fleſh, by its ſpring, will ſwell out the ſkin.

13. A SMALL receiver, placed over the hole in the pump plate, as ſoon as the air is exhauſted, will be ſtrongly preſſed down by the column of air which is over it.

14. IT is ſuppoſed by many, that this and other like effects, are cauſed by *ſuction*, or by ſomething within the glaſs drawing it down through the hole of the pump plate. But this is falſe, *as we ſhew by experiment*. For, if a ſmall glaſs be placed on one ſide of the hole, and covered with a larger, then while the larger is exhauſting, the ſmall one will be looſe; but when the air is let in again, the large one will be ſet at liberty, and the ſmall one, by the weight of the air, will be fixed.

THERE is no effect in nature produced by any cauſe that can be called *ſuction;* except that appellation be falſely applied to the *attraction of coheſion*.

15. SMOAKING tobacco, and ſucking the breaſt, are performed by the preſſure of the air. For, a vacuum being made in the mouth by drawing back, or bending down, the tongue, the air, by its weight, ruſhes through the pipe in ſmoaking; and by preſſing upon the breaſt in ſucking, forces the milk into the child's mouth.

The elaſticity of the air will appear from the following experiments.

16. If a bladder, containing a ſmall quantity of air, be faſt tied, and placed under the receiver, as the receiver is exhauſted, the bladder, by the expanſion of the included air, will ſwell out, and at length appear full blown.

17. If a glaſs bubble, having its neck placed in water, be covered with a receiver, as the air is exhauſted, that in the glaſs, by its ſpring, will make its eſcape, and will be ſeen riſing through the water in large bubbles.

18. If an egg, having a hole in the ſmaller end, be placed under the receiver, upon exhauſting, the air bubble contained in the great end, will, by its ſpring, drive out the contents.

19. If an egg be ſunk in a jar of clear water, upon exhauſting, the air will be ſeen to riſe from the pores of the ſhell, in innumerable fine ſtreams.

20. Take a bladder containing a little air, put it in a proper veſſel, and lay a weight upon it, cover the whole with a receiver, then work the pump, and the ſpring of the air will be ſeen to raiſe the weight.

21. If a ſhrivelled apple be placed under the receiver, and the air exhauſted, the air contained in the apple will expand itſelf, and cauſe the apple to appear plump and ſmooth.

22. If a piece of dry wood be ſunk in water, and covered with a recipient, upon exhauſting, the air contained in the pores of the wood, will expand itſelf, and riſe through the water in great quantities.

23. The experiment will ſucceed with green wood, leaves, &c. but the quantity of air thrown out will not be ſo great. From this it is evident, that there are air veſſels in vegetables.

24. If a piece of gold, &c. be put in water under a receiver, on exhauſting, the air contained in the pores of the ſurface of the metal, will expand itſelf, and appear all over the ſurface.

25. If a ſmall bladder, with a little air and a weight in it, be faſt tied and ſunk in water, upon exhauſting, the air contained in the bladder will expand itſelf, and cauſe the bladder and weight to ſwim.

26. Also, if a cork be juſt made to ſink, by fixing lead to it, it will be brought to the top, by the air bubbles adhering to its ſurface.

27. If a jar of clear water be placed under the receiver, upon exhauſting, the air will expand itſelf, and may be ſeen to riſe from every part of the water in innumerable bubbles.

28. If we uſe freſh beer inſtead of water, the air bubbles will not burſt, becauſe the beer is more viſcid, but will riſe with a fine frothy head.

29. Join a tall receiver, exhauſted of its air, to the top of a veſſel about half filled with water, a pipe going down near the bottom of the veſſel, open the cock, and the ſpring of the air acting upon the ſurface of the water, will cauſe it to riſe in the receiver with great velocity, and will make a beautiful fountain.

30. If a phial of hot water be placed under the receiver, as ſoon as the preſſure of the air is taken off its ſurface, it will begin to boil with great rapidity. A much leſs degree of heat is ſufficient to cauſe the phænomenon in *a vacuum*, than when under the compreſſion of the atmoſphere.

31. If a fiſh be put into a jar of water, and covered with a recipient, as ſoon as the preſſure of the atmoſphere is removed, the air contained in the air bladder will expand itſelf, and cauſe the fiſh to ſwim; but it will not very readily die.

32. If we put a mouſe, rat, cat, &c. under the receiver, and exhauſt the air, the animal will immediately die. From whence it appears, that air is abſolutely neceſſary for ſupporting the lives of theſe, and all other kinds of large animals.

33. But *inſects, reptiles, &c.* will not die *in vacuo.*

34. Air is neceſſary for the ſupport of fire and flame; becauſe burning coals, or a lighted candle will inſtantly go out *in vacuo.*

35. Explosions are cauſed by the reſiſtance and concuſſion of the air; for gunpowder will not flaſh *in vacuo.*

36. It is owing to the reſiſtance of the air, that light and heavy bodies do not fall equally faſt. For, *a guinea and a feather* will deſcend to the bottom of a tall receiver when exhauſted, in the ſame time.

37. That the air is neceſſary for the ſupport of vapour, is evident; for as ſoon as the receiver begins to be exhauſted, the vapour may be ſeen deſcending like a miſt.

38. The mercury in a thermometer placed under a receiver, falls during the exhauſting, and riſes again when the air returns.

See an ingenious account of theſe phænomena, in the Philoſophical Tranſactions, for 1788, by Eraſmus Darwen, of Derby, M. D.

39. That ſound is conveyed from place to place by the medium of the air, will appear by the following experiments.

If we place a bell upon the plate of the pump, and cover it with a receiver, and the bell be rung, the ſound will be much weaker than when in the open air, though the receiver be not exhauſted. If the receiver be well exhauſted, the ſound will not be audible, except very near the pump; but as a perfect vacuum cannot be made, the ſmall quantity of remaining air, will faintly convey the pulſes to the glaſs, which, by a tremulous motion, will convey them to the outward air. From this it appears, that ſound moves through the air, without the air being carried along with it.

40. That the preſſure of the ſurrounding air upon the receiver is not the cauſe of diminiſhing the intenſity of ſound, appears by the following experiment.

Cover a bell with a receiver, in which let the air remain. Cover this with a larger receiver. Condenſe the air betwixt them, and the ſound will be equally ſtrong, whether there be two or four atmoſpheres thrown upon the ſurface of the firſt receiver.

If an elaſtic body be ſtruck, or otherwiſe put in motion, it will continue to vibrate backward and forward for ſome time. The particles of air, which are near it, will by its quick vibrations, be put into the ſame tremulous motion with itſelf, and they, in their approach to thoſe which lie next them, will communicate it to them alſo; and ſo on to a conſiderable diſtance, depending on the intenſity of the ſtroke, and the nature of the ſonorous body.

THESE aerial pulſes, or waves, are propagated from the ſounding body, in con-centric ſpheres or ſhells, decreaſing in denſity as the ſquares of the diſtances increaſe. Hence a perſon at the diſtance of one mile from a ſonorous body, will hear the ſound four times as loud as he would do at the diſtance of two miles, &c.

THE velocity of ſound, according to the moſt accurate experiments, is at the rate of 1142 feet per ſecond. All ſounds, whether ſtrong or weak, move with the ſame degree of velocity, and nearly as faſt when they move againſt the wind, as when they move with it. But they may be heard much further in the direction that the wind blows, than in the contrary.

THE velocity of ſound increaſes with the elaſticity of the air, and is therefore ſomething greater in ſummer than in winter. Yet ſounds are more audible in winter than in ſummer, becauſe the air is more denſe. For the ſame reaſon, ſound is much ſtronger in a valley, than upon the top of a mountain, where the air is leſs condenſed by the weight of the incumbent atmoſphere.

As ſound is propagated from the ſonorous body in all directions, if it happens to ſtrike againſt rocks, buildings, woods, &c. the pulſes will be reflected back, and the ſound repeated, which is called an *echo*.

If a muſical chord be put in motion, all its vibrations, whether great or ſmall, will be performed in the ſame time; and therefore the chord, however ſtruck, will always produce the ſame note.

In order to produce different notes from the ſame ſtring, either the length or the tenſion of the ſtring muſt be altered.

If we take eight muſical ſtrings of the ſame thickneſs, and ſtretch them with equal weights, and if we make their lengths as, 100, 88.8, 80, 75, 66.6, 60, 53.3, 50, they will ſound the notes of the *diatonic ſcale*, viz. C, D, E, F, G, A, B, C, yet the ſounds of the higher notes would be more agreeable, if the ſtrings were ſmaller and longer, and their tenſion leſs.

If two ſtrings perform their vibrations in the ſame time, the note or tone produced is called an *uniſon*, and is the moſt perfect concord. If one ſtring performs two vibrations while the other performs one, they will ſound an *octave*, which is the next perfect. If one performs three for the other two, they will ſound a *fifth*. If one four for the other three, a *fourth*. If one five for the other four, a *third greater*.

If two muſical chords, placed near each other, be tuned uniſon, and one made to vibrate, the other will vibrate alſo. If the ſtring which is ſtruck be an octave above the other, the two extremes of the other will ſound uniſon with it, while the middle point remains at reſt. In the ſame circumſtances the ſame effect is produced by all kinds of ſonorous bodies; for, the vibrations of the air when put into a tremulous motion by the ſounding body, agree exactly with thoſe which may be produced by the body at reſt, and the vibrations of this reſting body, which in ſome faint degree are cauſed by the firſt impulſes of the vibrating air, are by its correſponding motion, continually increaſed.

That the air may be condenſed, is evident from the following experiments.

41. Let a ſtrong receiver, with a full blown bladder under it, be firmly ſcrewed down upon the plate of the pump; then with a ſyringe, or with the pump, if it be of *Smeaton*'s conſtruction, force in a quantity of air, and the bladder will begin to contract or ſhrivel up. Whence it is evident, that the air in the bladder is condenſed or ſqueezed into a leſs ſpace than it poſſeſſed before: and as ſoon as

the cock is opened, and the preſſure removed, it will again expand itſelf, and fill the bladder.

The condenſation ought not to be too great, when the receiver is of glaſs, leſt it ſhould burſt, which might be attended with bad conſequences.

If only a double atmoſphere be forced into a receiver of five inches diameter, and eight inches high, there will be a force of 1680lb. acting againſt its inner ſurface; if a treble atmoſphere, 3360lb.

42. If a glaſs bubble, with its neck immerſed in quickſilver, be placed under the receiver, and a double atmoſphere forced in, half the capacity of the bubble will be filled with quickſilver, and the air which in its natural ſtate, filled the whole capacity, will be compreſſed into one half thereof.

43. If air be condenſed upon the ſurface of water in a ſtrong veſſel, it will cauſe it to ſpout through the tube of communication with a ſurpriſing velocity, and will make a beautiful fountain, or jet d' eau.

Gaſſes.

These factitious airs, like atmoſpheric air, are tranſparent, and permanently elaſtic. There are various kinds; ſome of which are natural, others artificial productions. They have alſo different properties.

THEY may all be obtained by putting the proper materials in a flaſk, the mouth of which is cloſely fitted with one end of a bended tube, by means of a piece of cloth, leather, &c. The other end of this tube is placed under the mouth of a jar, filled with water or quickſilver, and inverted in a baſon of the ſame fluid.

44. *Fixed air*, or gas, is often found in deep pits, wells, &c. and may be produced by pouring acid of vitriol, diluted with water, on chalk, marble, ſpar, or any calcareous ſubſtance: it is alſo produced by ale, &c. when in a ſtate of fermentation. It is heavier than common air; is readily abſorbed by water, to which it gives a fine ſparkling appearance, and enables it to become a ſolvent for iron, &c. It deſtroys life, and extinguiſhes flame.

45. *Inflammable air* is frequently found in mines; and may be produced by diſſolving iron in diluted vitriolic acid. It is alſo produced by combuſtion, putrefaction, &c. and therefore abounds wherever theſe proceſſes are carried on. One kind of inflammable air burns in a gentle manner, another explodes with prodigious violence. It is much lighter than common air, and is highly noxious.

AIR, which will burn without exploſion, may be obtained by letting common air paſs through burning oil into an exhauſted receiver.

46. *Nitrous air.* To obtain this kind of air, pour the acid of nitre on braſs, copper, zink, or iron.

THIS is uſed for trying the goodneſs or purity of other kinds of air. When mixed with common air, it changes the colour, and diminiſhes the quantity. If mixed with air perfectly noxious, it makes no change.

47. DEPHLOGISTICATED, or pure air, is obtained from the freſh leaves of plants; by ſtrong acid of vitriol and red lead; or moſt copiouſly from nitre, in an earthen retort, urged by a ſtrong fire.

A GIVEN quantity of this will ſupport life much longer than the ſame quantity of common air; and makes the flame of a candle exceedingly brilliant.

FOR the above, water may be uſed to place the jars in; but for the following, quickſilver is found neceſſary.

Vitriolic acid air. To concentrated oil of vitriol, add olive oil, and apply a little heat.

Marine acid air. Pour acid of vitriol on ſea ſalt.

IF any ſubſtance, containing much phlogiſtion, is introduced into this gas, the gas is changed to inflammable air; and if it is mixed with about three times its quantity of common air, the flame of a candle burning in it will appear green.

Fluor acid air. Pour concentrated vitriolic acid on pounded fluor ſpar or blue John.

Nitrous acid air is obtained by heating nitrous acid; but this acts upon the quickſilver. Hence it becomes difficult to examine its properties. It efferveſces with eſſential oils, and is entirely abſorbed by water, to which it communicates the properties of the nitrous acid.

Alkaline air. Apply heat to volatile alkali. If this gas is mixed with marine, or vitriolic acid air, they unite, and form ſal-ammoniac, which precipitates ſomething like a white cloud.

AIR is made noxious by the putrefaction of vegetables, or animal ſubſtances; by the burning of candles; by animal reſpiration; by the calcination of metals; by the efferveſcence of iron-filings and brimſtone; by the effluvia of white paint; by exhalations from putrid marſhes, &c. From hence it is evident, that much air is daily corrupted, and without ſome remedy, the whole atmoſphere would at length become peſtilential.

How air made noxious is again purified, or rendered fit for breathing, has long been a ſubject of enquiry. But it appears by ſome late experiments, made by Dr. Prieſtly, that *water* and *growing vegetables* tend to reſtore it to a ſtate of purity; which diſcovery may be of the greateſt importance to mankind.

The air is an elaſtic fluid, capable of being expanded by heat, and contracted by cold. Hence if any part be heated, it will be rendered ſpecifically lighter than the adjoining air, and will therefore riſe into the higher parts of the atmoſphere; and the neighbouring air, by its weight, will ruſh into its place, and thereby a ſtream of air or wind will be produced. Thus we find the air ruſhing through the key-hole, chinks, crevices, &c. into a cloſe room where a great fire is made. And the rarefaction made by the heat of the ſun, is the cauſe of all the *regular* winds, whether general or periodical. For the air to which the ſun is vertical, is rendered hotter than in any other region, and is therefore conſtantly riſing into the upper parts of the atmoſphere, while the heavier air from north and ſouth, is moving in to ſupply its place. Under the equinoctial it blows nearly from the eaſt point; but as the diſtance increaſes, it varies more and more on both ſides, till about the 30th degree of latitude, where, on the north ſide it blows from the N. E. and on the ſouth ſide from the S. E. But this is to be underſtood only of open ſeas; for the direction is altered by hot ſands, mountains, &c. and the wind generally blows towards the land. Hence we have the reaſon of the periodical trade winds, or monſoons, which blow ſix months in one direction, and ſix months in the contrary, *as is more fully explained in the lecture.*

LECTURE IV.

Of Hydroſtatics.

HYDROSTATICS is that part of philoſophy which treats of the *properties*, *preſſure*, and *laws* of fluids.

A FLUID is generally defined to be a body, whoſe parts move freely among themſelves, and therefore yield to the leaſt partial preſſure. From whence it is ſuppoſed, that the particles of a fluid are ſmall, round, ſmooth, and hard. That fluids are porous, is evident from different phænomena.

All fluids, except air, are incompreſſible. That is, they cannot be forced or ſqueezed into a ſmaller ſpace than what they naturally poſſeſs. *

HENCE it follows, that the ocean, and other deep waters, muſt be every where of the ſame denſity; that is, they will not be more denſe at the bottom than at the top. *Yet the preſſure will be in proportion to the depth,* as is eaſy to conceive, by ſuppoſing a fluid compoſed of a number of thin plates, piled one upon another. For it is evident, that the higher the column, the greater will be the preſſure upon the loweſt.

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* Some have concluded, that water may be compreſſed in a ſmall degree.

This is proved by putting the open end of a narrow tube, into a wider one almoſt filled with water; for, as the ſmall tube deſcends, the water is ſeen to riſe in it, in proportion to the depth, though reſiſted by the ſpring of the internal air.

The preſſure of fluids, at the ſame depth, *is every way equal;* as upwards, downwards, and ſideways; and is always *in proportion to the perpendicular altitude,* without any regard to the quantity. That is, a ſluice will be equally as much preſſed in the ſide of a pond four yards in diameter, as it would be if the pond was four miles in diameter.

If a piece of flat lead be held cloſe to the bottom of an open cylinder covered with leather, and placed more than twelve times its thickneſs below the ſurface, it will be ſuſtained by the upward preſſure of the water.

Let two round boards be put together with leather, after the manner of bellows; in the middle of the upper board fix a long tube, through which pour water into the bellows; and the higher board will be raiſed by the upward preſſure, though a conſiderable weight be laid upon it.

Let the upper board of theſe bellows be fixed, and to the bottom faſten a wire, which coming through the tube, may be hooked to the end of a ſcale beam; then put weights into the ſcale at the oppoſite end, till the water be ſeen riſing above the upper board. Now ſuppoſing the weight ſufficient for that purpoſe be two pounds, then muſt the bottom of the bellows neceſſarily ſuſtain a preſſure of that weight, for the two ſcales are juſt balanced. If to theſe weights another pound be added, the water will riſe in the tube, till its preſſure at the bottom, being increaſed to three pounds, reſtores the equilibrium. In the ſame manner, for every additional pound thrown into the ſcale, the water will riſe through an equal ſpace in the tube, and preſerve, by its preſſure, a counterpoiſe.

For example, let us ſuppoſe that every pound put into the ſcale raiſes the water one inch in the tube: then if it be raiſed 20 inches, the bottom muſt be preſſed with a force of 20 pounds, although the abſolute weight of the water be not more than 2 pounds.

This very ſingular effect, which is generally called the *hydroſtatic paradox*, is thus accounted for. The upward preſſure at the ſame depth, is equal to the downward preſſure, and therefore the fixed part is preſſed upwards with a force equal to the weight of a column of water of the ſame altitude with that in the tube, and of a diameter equal to the ſaid fixed part, which *part* re-acts upon the water, and cauſes it to preſs upon the bottom with a force equal to the weight of a column of the before mentioned altitude, increaſed by the depth of the bellows, and of a diameter equal to that of the bottom.

Take an open glaſs cylinder, over one end of which let a bladder be tied flaccid. Fill the cylinder, to any height at pleaſure, with water, and by its weight the bladder will be made convex on the lower ſide. Put the cylinder gradually into a large veſſel of water, and while the ſurface of that in the cylinder is higher than that in the veſſel, the bladder will continue to be bulged downward. As ſoon as their ſurfaces become level, or of the ſame height, the bladder will be flaccid. If the cylinder be ſunk deeper, the bladder will become convex on the upper ſide, by the ſuperior upward preſſure of the water in the veſſel, becauſe its ſurface is the higher.

Let a ſmall and wide tube be joined together at the bottom; pour water into the wide tube, and it will riſe in the ſmall *one* to the ſame height, but not higher. Whence it is evident, that the preſſure is in proportion to the perpendicular altitude. For, were it as the quantities which the tubes contain, the altitude in the ſmall one ſhould be, to the altitude in the wide one, as the ſquare of the diameter of the wide tube, is to the ſquare of the diameter of the ſmall *one.*

From hence we ſee the reaſon of conveying water by aqueducts; or why water may be conveyed to any place not higher than the ſource, though a valley intervene, by means of a bended pipe. For it is evident the water will always riſe to the level of the ſpring, whatever the form of the pipe be.

The preſſure of a fluid againſt the ſides or bottom of a veſſel, may be computed as follows; *for the bottom;* multiply the depth in inches by .03617, and the product thence ariſing, by the area of the bottom, in inches. This laſt product will be the whole preſſure upon the bottom in pounds avoirdupoiſe.

For a ſide; multiply the area under water, in inches by .03617, and that again by the depth of the centre of gravity, in inches; the product will be the preſſure, in pounds, as before.

The velocity with which water ſpouts out at a hole in the bottom or ſide of a veſſel, is equal to that which would be acquired by a heavy body, in falling from the ſurface of the water to the ſaid hole.

A heavy body will fall through a ſpace of 16.13

feet nearly, the firſt ſecond, and will thereby acquire a force which would carry it with an uniform motion, over a ſpace of 32.26 feet per ſecond.

THEREFORE, if a hole be made in the ſide of a veſſel, or through the breaſt of a dam, at the depth of 16.13 feet below the ſurface, the water will ſpout out, with a velocity of 32.26 feet per ſecond.

THE velocity with which water ſpouts out at holes, made at different depths below the ſurface, is as the ſquare root of theſe depths. *As for example:* ſhould it be required to find the velocity, with which a fluid would ſpout through a hoſe 9 feet below the ſurface, it would be, *as* 4 (the ſquare root of 16) *is to* 3 (the ſquare root of 9) *ſo is* 32 (the velocity at 16 feet below the ſurface) *to* 24 *feet, the velocity per ſecond, required.*

OR, if the ſquare root of the depth in feet be multiplied by 8, it will give the velocity in feet, per ſecond.

THE following Table (which may be of ſervice to thoſe who are concerned in water-works) ſhews the velocity per ſecond with which water ſpouts from holes made in the ſide of a veſſel, from one to ſixty feet below the ſurface.

Depth in Feet.	Velocity per ſecond in Feet.	Depth in Feet.	Velocity per ſecond in Feet.
1	8.	17	32.96
2	11.28	18	34.
3	13.84	19	34.88
4	16.	20	35.76
5	17.84	21	36.64
6	19.6	22	37.52
7	21.12	23	38.4
8	22.64	24	39.2
9	24.	25	40.
10	25.28	30	43.84
11	26.64	35	47.04
12	27.76	40	50.56
13	28.88	45	53.68
14	29.92	50	56.56
15	30.96	55	59.2
16	32.	60	62.

N. B. In this table I have taken the velocity at 16 feet, to be 32 feet per ſecond, not regarding the decimal.

It is neceſſary that there be a free paſſage to the hole from which the fluid ſpouts, otherwiſe the velocity will be greatly retarded.

THE quantity of water diſcharged at any depth below the ſurface, while the aperture remains the ſame, will be as the velocity at that depth. *As for example:* Should 8 pints be diſcharged through a hole, one foot below the ſurface, in a certain time; then an equal hole, made two feet below the ſurface, would diſcharge 11.28 pints in the ſame time; and ſo on, as in the table.

SPOUTING fluids, when applied to wheels, ſhould ſtrike them in the direction of a tangent; or they ſhould flow in ſuch a manner, were the float-boards or ladles away, as to paſs by the wheel, only juſt touching its circumference. If this be not the caſe, a conſiderable part of the force will be deſtroyed, and the velocity proportionably retarded.

Of Solids immerſed in Fluids.

IF a ſolid be immerſed in a fluid, it loſes juſt ſo much of its weight, as is equal to the weight of its equal bulk of the fluid. Take a cylindric bucket, and a ſolid cylinder of braſs, &c. which will exactly fill it. Let the bucket be ſuſpended from the end of a ſcale beam, and the cylinder from the bottom of the bucket. Balance them by putting weights into the oppoſite ſcale. Then place the cylinder in a jar of water, and the equilibrium will be deſtroyed. Pour water into the bucket till it be full, and it will be reſtored again. *Whence it is evident, that the cylinder is reſiſted by the weight of its bulk of water.*

From this it appears, that if a body be lighter than water, bulk for bulk, it cannot deſcend, becauſe it is reſiſted by the weight of its equal bulk of water. If it be heavier, it will loſe ſo much of its weight, as is equal to the weight of its bulk of water, and deſcend with the reſt. If it be the ſame weight with water, bulk for bulk, it will remain at reſt in any part of the water. *All which is ſhewn by ſmall glaſs images, whoſe ſpecific gravities may be increaſed at pleaſure.*

Relative or *ſpecific gravity* is the gravity or weight of one body, compared with the weight of another, of equal magnitude.

If a cubic inch of gold be twice the weight of a cubic inch of copper, then are their ſpecific gravities ſaid to be as two to one.

The ſpecific gravity of any kind of matter is eaſily found by the *hydroſtatic-balance*. For if we ſuſpend the body, whoſe ſpecific gravity we would know, from the bottom of a ſcale, by a fine thread, and then balance it exactly, firſt in *air*, and then in *water*, it will be, as the difference between the weight in water and in air, is to the weight in air; ſo is the ſpecific gravity of water, to the ſpecific gravity of the body required.

Hence, if the weight of the body in air, be divided by what it loſes in water, the quotient will ſhew how many times it is heavier than water.

In order to find the ſpecific gravities of fluids; let a ſolid piece of glaſs be ſuſpended from a ſcale, as before, and exactly balanced in the air: if then it be immerſed in different kinds of fluids, the weights put into the ſcale over it every time, to reſtore the equilibrium, will expreſs the relative gravities of the fluids.

The ſpecific gravities of different bodies, found by the above proceſs, are expreſſed in the following table.

			oz.
A cubic Foot of	Pure Gold	weighs	19,640
	Standard Gold		17,150
	Pure Silver		11,091
	Standard Silver		10,000
	Lead		10,130
	Copper		9,000
	Braſs caſt		7,856
	Iron		7,645
	Tin		7,551
	Flint Glaſs		2,542
	Slate		2,750
	Dry Oak		925
	Pit-coal		1,272
	Ebony		1,177
	Ivory		1,862
	Dry Fir		546
	Mercury		13,610
	Rain Water		1,000
	Aqua-fortis		1,300
	Spirit of Wine		840
	Red Wine		993

The ſpecific gravity of fluids may be found by pouring a little mercury into a bended glaſs tube open at both ends, and then pouring into each leg a different kind of fluid, and in ſuch quantities, that the mercury in each leg may ſtand to the ſame altitude; and if the fluids poured in be of different altitudes, their ſpecific gravities will be reciprocally as thoſe altitudes.

The hydrometer is the moſt convenient inſtrument for diſcovering the ſpecific gravities of fluids. The only one made on true principles is always ſunk to the ſame mark in the ſtem, by weights placed on the top thereof. Hence the quantity of fluid diſplaced in every experiment, is exactly the ſame. If therefore we add the weight placed on the top, to the weight of the inſtrument, the ſum will be the weight of the fluid diſplaced.

Example. If when ſunk to the proper mark in *water*, the whole weight be 1000 grains; and, if when ſunk to the ſame mark in *rum*, the weight be 928, then is the ſpecific gravity of the former, to that of the latter, as 1000 to 928; the temperature in each being the ſame. *

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* An hydrometer, with many improvements, is made by Mr. J. Dicas, of Liverpool.

LECTURE V.

Of Hydraulics, &c.

THE ſyphon or crane is a bended tube, which being filled with water, and then inverted, the outward leg being continued below the ſurface of the water to be conveyed through it, the water in the longer leg, by its weight, will begin to deſcend, and that in the other, by the preſſure of the air, will be forced after it; provided the altitude of the ſyphon above the water does not exceed 33 feet.

Tantalus Cup.

THE phænomenon of this cup is owing to a concealed ſyphon, the higheſt part whereof is lower than the top of the veſſel, one leg reaching below the bottom, and the other communicating with the inſide, near the bottom. As the cup is filled with water, the ſyphon will alſo be filled; or the water will continue to riſe in the cup, till it runs over the bended part of the ſyphon, when the ſyphon will begin to run, and the cup will be emptied.

INTERMITTING ſprings are accounted for upon this principle. If a ſyphon is formed in the earth, and communicates with ſome cavity near the bottom; and if this receptacle be not ſupplied with water as faſt as the ſyphon will carry it off, it will then riſe, as in the cup, till the ſyphon begins to run, which will continue till the cavity be emptied, or till the water falls below the orifice of the ſyphon, and then it will ceaſe.

The Fountain at Command

Is a cylindric veſſel, about four inches wide, and five inches high, cloſed at both ends. In one end are inſerted, round the centre, five or ſix ſmall pipes, half an inch long, and one eighth in diameter. In the centre is ſoldered, a tube fourteen or eighteen inches long, and half an inch diameter; one end of this tube goes near the top of the veſſel, and on the other are ſoldered three claws to ſtand upon, and which raiſe the lower orifice of the tube about half an inch above the bottom of a cup, in which it is placed; in which bottom is made a ſmall hole. The veſſel being almoſt filled with water through the long tube, and then inverted, it will run out through the ſmall pipes into the baſon, and will riſe till it touches the lower end of the wide tube, and then the fountain will ceaſe to run; for as the air is kept from entering through the long tube, the preſſure of that on the outſide will ſupport the water in the veſſel. But as the water is conſtantly running out of the cup through the ſmall hole in the bottom, as ſoon as it falls below the orifice of the long pipe, the fountain will again begin to play.

Common Pump.

The action of this pump depends upon the preſſure of the air. A piſton, with a valve in it, being made to ſit the bore of the pump, is put down near a valve which is fixed below in the barrel. A little water is poured upon it to make it air-tight, and then, when it is lifted up, the column of air upon it is alſo lifted, and the ſpring of that below in the pump is weakened, and the water, by the preſſure of the air, is raiſed in the barrel, 'till its weight, together with the ſpring of the internal air, balance the outward atmoſphere. The ſtroke being repeated, when the piſton is put down, the air above the fixed valve makes its eſcape through the piſton valve. When it is raiſed the air below is again expanded, and the water raiſed as before, &c. until after a number of ſtrokes the water is raiſed above the piſton and brought up into the ciſtern, from whence it may run off.

In conſtructing a pump of this ſort, it is neceſſary that the valve be not fixed too high, viz. not more than 20 or 24 feet, and in ſome caſes not more than 15 feet above the ſurface of the water.

For although the preſſure of the atmoſphere will raiſe a column of water to the altitude of 32 or 34 feet (provided a perfect *vacuum* be made) yet the velocity with which it riſes, at any altitude above

24 feet, is too ſmall where any conſiderable quantity of water is to be raiſed. At the ſurface of the well the velocity with which it follows the piſton is upwards of 45 feet per ſecond, but decreaſes to the altitude of 34 feet, where it is nothing.

If the *wind-bore* or lower pipe be made too ſmall in proportion to the working barrel, the water will not riſe with a ſufficient velocity through the valve, to fill the vacuum in the working barrel left by the piſton, in which caſe the pump will be much harder to work; for whatever the column below the piſton wants of 32 feet, it will be added by the preſſure of the atmoſphere.

The velocity with which the piſton riſes, its altitude above the water, and the diameter of the working barrel, are all to be conſidered in computing the diameter of the wind-bore, or the diameter of the valve.

Those who are not able to adjuſt the dimenſions by theory, ſhould fix the valve near enough the ſurface of the water, as within 20 feet, for in this there is no diſadvantage in working the pump, as many people ſuppoſe.

For ſhould it be required, to raiſe water 40 feet, the weight of water to be lifted every ſtroke will be the ſame, whether the ſpear be 15 or 30 feet long.

In the firſt caſe there will be but half the quantity of water upon the piſton, that there will be in the ſecond, but as the weight upon the piſton at every ſtroke, is equal to the weight of a column of water of the ſame diameter with the piſton, and of an altitude equal to the diſtance between the ſurface of the water in the well, and the ſurface of that in the ciſtern, it can make no difference in what part of the pump the piſton plays, provided it be near enough the bottom: for though the water be forced up the lower part of the pump by the weight of the atmoſphere, yet the ſaid part is firſt exhauſted of its air by the piſton, which is conſtantly preſſed by the column of air above it with a force equal to the weight of the column of water below.

From hence it is evident, that while the working barrel remains the ſame, there can be no advantage in contracting either the lower or upper part of the pump: for it has been already proved, *that, while the bottom or piſton remains the ſame, the preſſure is in proportion to the altitude.*

Forcing Pump.

In this pump, the piſton is ſolid, or without a valve. A pipe with a valve in it is fixed in the ſide of the pump, juſt above the fixed valve; ſo that when the piſton is puſhed down, the water is forced out at the ſide pipe, and is hindered from returning by the valve. The ſide pipe may be of any length required, and by it the water may be forced to the tops of buildings, &c.

Lifting Pump.

In this pump, the ſpear goes in at the bottom, is wrought by means of a frame, and can therefore only be uſed in deep waters.

The draining Pump

Is made ſquare with a valve in the bottom: it is moſtly wrought in an inclined poſition, the piſton is made in the form of the fruſtum of a ſquare pyramid, the edges are fixed with cords to the ſpear. When it is lifted up, the water preſſes it cloſe to the pump, but when it is puſhed down, the ſides bend in, and give way for the water, ſand, gravel, &c. to riſe.

Archimedes' Screw

Is a tube open at both ends, coiled round a cylinder. When it is to be uſed it is placed in an inclined poſition, with the lower end in water, and upon turning it round, the water is brought out at the top.

Gervis' Engine

Consists of two buckets ſuſpended from wheels which have their diameters proportioned to the aſcent and deſcent. When the machine is at reſt, the tops of the buckets are nearly upon a level: they are ſupplied with water at the ſame time, but in ſuch a manner, that the bucket which raiſes the water is firſt filled, after which it runs over into the other. As ſoon as this has received a ſufficient quantity, it begins to deſcend, and raiſes the other, full of water, which when at the top, empties itſelf through a valve (opened by a lever ſtriking againſt a ſtud) into the reſervoir. At the ſame time the water runs out of the other bucket through a valve opened by a ſimilar contrivance. When both are emptied, they return to the place where they receive the water.

Dr. Barker's Mill.

The cylindric mill is a tall upright tube, into which, near the bottom, and on oppoſite ſides, two horizontal tubes are fixed.

When the water (which runs in at the top) has filled the arms and cylinder, the preſſure againſt the inſides of the arms will be as the height of the cylinder. Suppoſe the altitude to be 20 feet, the preſſure upon every inch will be 10.8lb. If an aperture of 6 inches in area be made in each arm, on contrary ſides, and near the ends; the preſſure on that ſide of the arm will be diminiſhed 64.8lb. but will remain the ſame againſt the other ſide; hence there will be a force of twice 64.8lb. or 129.6lb. acting at the ends, to turn the machine round.

Of the power of the above Mill.

Let a = the area of one aperture
b = the length of one arm
d = the altitude in inches
l = .5787 *oz.* avoirdupoiſe, the weight of a cubic inch of water
v = velocity per ſecond
n = diſtance of the reſiſtance from the centre

Then will adl = the preſſure when the mill is at reſt. And as $n : b :: adl : \frac{adlb}{n}$ = the force at n.

If we wiſh to increaſe the force by increaſing the depth, while the ſtream remains the ſame, the aperture at the bottom muſt be inverſely as the ſquare root of the altitude, or depth of water in the mill.

Suppose we make the depth equal to $4d$.

Then as $\sqrt{d} : v :: \sqrt{4d} : \frac{2v\sqrt{d}}{\sqrt{d}} = 2v$ hence $\frac{a}{2}$ muſt be again divided by 2 or $\frac{a}{4}$ for the area of one aperture, and the force or power of the mill, will be expreſſed by $2ald$, which is double what it was in the firſt expreſſion, or as the ſquare root of the altitude.

HENCE it appears, that the force will be as the ſquare root of the altitude, while the quantity of water remains the ſame.

BUT if the aperture remains the ſame, and the water remains ſufficient to fill the mill, the force will be as the altitude.

Centrifugal Machine.

ERSKINE's centrifugal pump conſiſts of an upright tube, which has a valve at the bottom. Into this tube are fixed two tubes, or arms, at the top, and oppoſite each other. There is alſo a hole in the upper ſide of one of the arms, through which water is poured, till the whole is filled: it is then cloſed, and to ſupport the water in the arms, each is furniſhed with a valve. Then by means of wheels and cogs, it is turned quickly round a perpendicular axis. The water in the arms acquires a centrifugal force, preſſes open the valves, and flies out, and to ſupply its place, the water is raiſed through the upright tube, by the preſſure of the atmoſphere; hence it is evident, that this pump cannot raiſe water much above 30 feet, nor ought it to be made much more than 20 feet high.

As all the methods of computing the force of the centrifugal pump, that I have ſeen, are exceedingly erroneous, and founded upon falſe principles, I have added the following note.

Of the Power of the Centrifugal Pump.

Let a = length of one arm
t = time of one revolution in ſeconds
$d = 16.1$ feet
$q = 3.14159$

Then as $\frac{d}{2q^2} : \frac{a}{2t^2} :: 1 : \frac{aq^2}{dt^2}$ the centrifugal force of the water compared with its gravity.

SECONDLY. *To find the altitude of a column which will be equal to the centrifugal force.*

As $\frac{d}{2q^2} : \frac{a}{2t^2} :: a : \frac{a^2q^2}{dt^2}$ the height in feet.

THIRDLY. *To find the velocity with which the water is diſcharged.*

FROM the principles of Hydroſtatics we ſhall have

As $4 : 32 :: \sqrt{\frac{a^2q^2}{dt^2} - h} : 8\sqrt{\frac{a^2q^2}{dt^2} - h}$; h being put for the height of the pump in feet. $\frac{q^2}{d} = .613$ hence the three following theorems.

THEOREM I.

$.613 \times \frac{a}{t^2}$ = the centrifugal force compared with the gravity, which is repreſented by 1.

THEOREM

THEOREM II.

$.613 \times \frac{a^2}{t^2} =$ the height of a column, the weight of which is equal to the centrifugal force.

THEOREM III.

$8\sqrt{.613 \times \frac{a^2}{t^2} - b} =$ the velocity of the water at the ends of the arms.

EXAMPLE.

Let $a = 3$ feet
$t = \frac{1}{2}$ ſecond
$b = 10$ feet

THEOREM I.

$.613 \times \frac{a}{t^2} = 7.356$, hence the centrifugal force is more than ſeven times the gravity.

THEOREM II.

$.613 \times \frac{a^2}{t^2} = 22.08$ feet, the height.

THEOREM III.

$8\sqrt{.613 \times \frac{a^2}{t^2} - 10} = 27.7$ feet per ſecond.

LET the diameter of the ends of the arms from which the water is diſcharged be required, ſo that the above pump may raiſe one gallon per ſecond.

Let $v = 27.7$ feet $= 332.$ inches, the velocity
$s = 141$ inches, or half a gallon, the quantity thrown out by one arm
$x =$ the area of the arm

Then will $x = \frac{s}{v} = .424$ inches, the area of the end of the arm, and the diameter will be found near $\frac{3}{4}$ inch.

WHICH pump will raiſe 60 gallons per minute to the altitude of 10 feet, but will be too hard labour for one man.

Newſham's Water Engine.

THE engine generally made uſe of for extinguiſhing fires, conſiſts of two pumps, which alternately force the water into a ſtrong air-veſſel, in the top of which a pipe is fixed, and extends near the bottom. When the water is riſen in the veſſel, to the bottom of the pipe, the air cannot make its eſcape; but as the water riſes, it compreſſes the air in the crown of the veſſel, which, by its ſpring, forcibly acts upon the ſurface of the water, and cauſes it to ſpout through the pipe with an exceeding great velocity, and by means of a proper contrivance at the top, may be thrown in any direction at pleaſure.

The

The Chain Pump,

Or rag pump, conſiſts of a number of pieces of wood or iron, of the ſame ſize, which are connected by a ſtrong chain, paſſing through the centre of each, the ends of which are linked faſt together. This chain is ſtretched by two ſmall wheels, having teeth of a proper ſize to admit the pieces of wood; ſo that by a winch, fixed upon the axle of the upper wheel, the chain is cauſed to aſcend on one ſide, and deſcend on the other. On the aſcending ſide they riſe up a cloſe groove, into which they are exactly fitted, ſo that they take with them as much water as can be contained between each piece of wood and the next. When they have reached the top, the water runs into a trough, which conveys it away.

Bucket Engine.

The working part of this engine is made with a beam in the form of an iſoceles triangle, the vertical angle of which is very obtuſe. The axle is placed in the baſe, and on the two equal legs are faſtened two troughs, to the ends of which are hung two large buckets, with a valve in the bottom of each.

By a proper pipe the water is delivered exactly over the axle, and a diviſion being placed in the troughs at the vertical angle, it can only run down into one bucket at once. The buckets are ſupported by a catch, till nearly full, and then they

fall

fall with a jerk alternately; as the diviſion is firſt thrown on one ſide the ſtream, and then on the other. When the buckets are at the bottom, they are emptied through the valves, opened by ſtuds.

This is only the machinery for working either common or forcing pumps.

Steam Engine.

The fire-engine conſiſts of a large beam, boiler, cylinder, &c. In the cylinder, which ſtands upright, a piſton is ſuſpended from one end of the beam, and to the other, are fixed the pump rods. The cylinder and boiler are made to communicate by means of a pipe, in which is placed a plate called the regulator. The boiler is filled with water to a certain depth, which by fire is converted into a vaſtly elaſtic ſteam, * the ſtrength of which is known by its lifting a valve at the top of the boiler, called the ſteam clack. When the regulator is open, the ſteam enters into the cylinder, and drives out the air through a ſmall hole, covered with a valve, called the ſnifting clack. When the cylinder is filled with ſteam, the regulator is ſhut, and the injection cock is opened, by which a jet of cold water is let into the cylinder, from a ciſtern fixed above. This jet condenſes the ſteam, and makes a ſufficient vacuum for the piſton to deſcend, which is immediately brought down by the weight of the atmoſphere. In its deſcent it ſhuts the injection cock, and opens the regulator; the ſteam again enters into the cylinder, and balancing the preſſure of the air, the piſton is raiſed by the weight of the pump rods at the other end of the beam: as it riſes, it ſhuts the regulator, and opens the injection cock: the ſtroke is again repeated, and the water in the pumps is raiſed, and diſcharged at the top.

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* It has been maintained by many, that water, when converted into ſteam, fills 13,000 times its original ſpace. But from various experiments made in order to aſcertain the expanſion in the cylinders of ſteam-engines, I conclude it is much leſs. When the boiler ſtands at a diſtance, the ſteam is cooled, and part of it is condenſed by the tubes in which it is conveyed; much of it is alſo condenſed by the cylinder. By many experiments made on a cylinder, three feet in diameter, one gallon of water produces about 800 gallons of efficacious ſteam. By other experiments made by Mr. Bateman, of Whitehaven, with a cylinder, five feet eight inches diameter, one gallon of water will produce 1532 gallons of ſteam, but never more.

The ſteam is ſeldom much ſtronger or weaker than the outward air: if it be $\frac{1}{15}$ ſtronger, the engine will work well. At a mean, the preſſure upon every ſquare inch of the piſton, will be 14lb. and upon every foot 18cwt. But in practice the weight at the other end of the beam, ſhould not be more than half the preſſure upon the piſton, in order that the engine may ſtrike ſufficiently faſt.

The ſteam-engine has lately been made with an inverted piſton, to ſave the expence of a beam. The contrivance is ingenious, but it does not work any thing near ſo well as when made with a beam.

Patent Steam Engine.

SINCE the firſt invention of the ſteam-engine, by Meſſrs. Newcomen and Cowley, of Dartmouth, towards the latter end of the laſt century, it has undergone ſeveral alterations; the greateſt of which has been made by Meſſrs. Boulton and Watt. Inſtead of the preſſure of the air, they have ſubſtituted the elaſtic force of the ſteam; and inſtead of condenſing, as in the common form, a vacuum is made in an adjoining veſſel, into which enters a jet of cold water, which, with the condenſed ſteam, is removed by a pump. By this contrivance, the cylinder is always kept hot, and conſequently requires leſs ſteam. In this conſtruction, the top of the cylinder is cloſed; a rod paſſes through a collar in the cover; and a communication is occaſionally opened between the top and bottom of the cylinder.

WHEN this engine is applied to communicate a rotatory motion, the ſteam alternately preſſes upon the upper and lower ſide of the piſton, which, in this caſe, is not ſuſpended from the beam by a chain, but fixed in ſuch a manner, as to preſs the beam with equal force, whether riſing or falling.

LECTURES

LECTURES VI. & VII.

Of Electricity.

ELECTRIC fire, or electric fluid (or by whatever name we may call this ſubtle active matter) ſeems to be inherent in all bodies; but does not appear unleſs the equilibrium is deſtroyed; which may be done by rubbing vitreous or reſinous ſubſtances; which ſubſtances are called *electrics*, or non-conductors. Metals and bodies which contain much phlogiſtion, are conductors of electricity, and are called *non-electrics*.

If metallic bodies are inſulated (ſupported by electrics) their quantities of electricity may be increaſed, which at the approach of a ball of metal, &c. will make its eſcape with a ſnap, and will ſhine or appear like a ſpark of fire.

Bodies, which contain unequal portions of electricity, attract each other; if equal portions, they repel.

If both ſides of a jar be covered with tinfoil, except a circle round the top of about two inches in breadth, and a quantity of electricity be thrown upon the inſide, the outſide (being connected with the Earth) will part with an equal portion. After which, if a metallic communication is formed between the ſides, the jar is diſcharged, or the electricity eſcapes from the inſide to the outſide, with a ſnap and flaſh.

From which it appears, that if one ſide of an electric contains more than its natural quantity, the other will contain leſs.

Hence, if the upper regions of the atmoſphere contain more than their common quantity, the ſurface of the Earth ſhould contain leſs, and *vice verſa*, which has always been obſerved to be the caſe in thunder ſtorms.

From modern obſervations it is certain, that lightning is a large quantity of electricity, paſſing between bodies which contain unequal portions thereof. Sometimes deſcending from the cloud to the Earth; ſometimes riſing from the Earth to the cloud, &c.

Lightning always precedes the thunder, and is the cauſe thereof. It may be conſidered as a ball, moving through the air with a velocity ſufficiently great to leave a vacuum behind it. The air, which was divided and condenſed in the vicinity of the paſſage, by its elaſticity, immediately coaleſces, and produces the noiſe.

The duration of the thunder-peal is accounted for, in the moſt ſatisfactory manner, from the progreſſive motion of ſound: not by reverberation, or zones of inflammable air, as ſome have ſuppoſed.

If a lightning paſſes from cloud to cloud in various directions before it reaches the Earth, the time of this paſſage is momentary.

The velocity of light is 200,000 miles in one ſecond; that of ſound, 1142 feet. Hence the lightning will be ſeen the very inſtant that it moves. But if no part of the vacuum ſhould be nearer than one mile, it would be about five ſeconds before the ſound could be heard: or there would be five ſeconds between ſeeing the lightning, and hearing the thunder. And if another part of the vacuum ſhould be at the diſtance of two miles; from that part, the ſound would require ten ſeconds to paſs over it. Hence, the thunder-peal would in that caſe continue five ſeconds. And by meaſuring the interval between the lightning and the beginning of the thunder, we may nearly eſtimate the diſtance of the neareſt approach of the lightning, to the place where we are. And the number of ſeconds between ſeeing the lightning, and the end of the thunder, will give us the greateſt diſtance of the ſame lightning. When the interval is one ſecond, the diſtance will be 381 yards,

When 2 ſeconds	761 yards
3	1142
4	1523
5	1.08 mile
6	1.3
7	1.51
8	1.73
9	1.94 mile, or near 2 miles.

To ſecure buildings from the effects of lightning, a bar of metal ought to be ſo placed, that one end may be elevated above the higheſt part of the building, and the other ſunk deep in the Earth, or carried into water.

Two lectures are given upon this ſubject, illuſtrated by experiments made with a cylinder 19 inches diameter, and conductors of 12 inches diameter, with other neceſſary apparatus.

LECTURE VIII.

Of Optics.

IT is manifeſt from a number of experiments, that *light is a real ſubſtance or body*, and that it conſiſts of particles inconceiveably ſmall; otherwiſe they could not pervade the pores of glaſs, diamond, &c. The wiſdom of the creator is abundantly manifeſt, and perhaps as fully diſplayed in the ſmallneſs of the particles of light, as in any part of the creation. Light is emitted from every point in the ſurface of a luminous body, in right lines, and with a velocity of 200,000 miles in a ſecond of time, which is inconceivable and unparrallel'd.

As light is propagated in ſtreight lines, it muſt decreaſe, as the ſquares of the diſtances increaſe; *that is*, if at the Earth we have a certain quantity or degree of light and heat from the Sun, then at twice that diſtance there will be but $\frac{1}{4}$ part of that quantity; and at three times the diſtance but $\frac{1}{9}$ part thereof: but at half the diſtance there will be 4 times as much, and at one third of the diſtance, 9 times as much. So it will be found, that at *Mercury* there is about $6\frac{1}{2}$ times the light that we have; at *Venus*, near twice as much; at *Mars*, about $\frac{1}{3}$; at *Jupiter*,

Jupiter, $\frac{1}{28}$; and at *Saturn*, $\frac{1}{100}$ part of the light and heat which we have.

If a ray of light, coming from the ſurface of a luminous object, falls upon a plain mirrour, it will be ſo reflected, that the *angle of reflection* will always be equal to the *angle of incidence*.

Light, alſo, in paſſing out of one medium into another of different denſity, is *refracted*, or bent out of a ſtreight line, and the more ſo as the medium is more denſe.

The white light of the Sun is *heterogeneal*, or of different kinds, and each kind differently refracted, or bent out of its way in paſſing through the ſame medium, and appears alſo of a different colour. Theſe rays which are *leaſt refrangeable*, excite the idea of *red;* the ſecond ſort, of *orange;* the third, of *yellow;* the fourth, of *green;* the fifth, of *blue;* the ſixth, of *indigo;* and the ſeventh, of *violet*.

If a beam of the Sun, coming through a ſmall hole into a dark room, fall upon the ſide of a triangular glaſs priſm, it will, upon the oppoſite ſide of the room, form an oblong and coloured image of the Sun.

Now, if theſe different ſorts of light were not differently *refrangeable*, the image after refraction would continue to be round; but we find it is not, and that the red light is leaſt, and the violet the moſt refrangible.

That theſe different kinds of light really exiſt in the light of the Sun, and that the image is not ſpread out by the incident rays being diſturbed, ſhattered, or ſplit by the glaſs, appears from a number of experiments, *as ſhewn in the lecture.*

Light falling upon the ſurface of bodies, is in part *reflected*, and in part *imbibed.* If the parts of a body be ſo diſpoſed as to reflect all the rays which excite the idea of red, and imbibe the reſt, that body muſt appear red. If a body reflects all the green rays, and imbibes the reſt, it muſt appear of a green colour, &c. Every body, therefore, appears of ſuch a colour, as would be produced by a compoſition of the different kinds of light which it reflects.

Bodies which reflect one kind of light, and refract the others, will appear of different colours by refraction and reflection.

The phænomenon of the *rainbow* is cauſed by the Sun's rays being ſeparated by the drops of falling rain, *as is ſhewn in the lecture*, by filling a glaſs globe with water, and letting a beam of the Sun, coming through a ſmall hole into a dark room, fall upon it.

If parallel rays fall upon a *concave mirrour*, they will be reflected back to a point, diſtant from the vertex of the mirrour equal to half the radius of concavity. This is called the *ſolar focus*, or burning point: for the rays of the Sun meeting in this point, burn very intenſely. There is alſo in this point, an image formed of the object, from which the rays proceed. But if the object be brought nearer, ſo that the rays do not fall parallel, the image will not be formed in the ſolar focus, but further from the mirrour: and as the object is brought nearer, the image will recede, till they meet in the centre of the ſphere of concavity, where they will be of equal magnitude, but the image inverted.

As the object is brought nearer the focus, the image will conſtantly fly off, till the object arrives at the focus, and then the rays will be reflected parallel among themſelves, ſo that no image can be formed. If the object be between the focus and mirrour, the image will be formed behind the mirrour, erect and magnified.

Parallel rays falling upon a plain glaſs of equal thickneſs, cannot be converged to a focus, but will proceed parallel after refraction.

If one ſide be plain, and the other convex, parallel rays will be converged to a point, at a diſtance equal to the diameter of the ſphere of convexity. If it be double, and equally convex, they will meet in the centre of the ſphere of convexity.

In theſe points, images will be formed of the objects which the rays proceed from. If the objects be brought near, the images will be formed further from the glaſſes, than the above mentioned points.

If the diſtance of the object be equal to twice the focal diſtance of the glaſs, the image will be formed at the ſame diſtance on the other ſide, and of the ſame magnitude with the object, but inverted.

Concave glaſſes do not form images; but parallel rays, after refraction, proceed diverging as if they came from a point, diſtant from the glaſs, equal to the diameter of the ſphere of concavity, if it be *a plano concave;* but as if they came from the centre, if it be *a double concave.*

The *human eye* is of a globular form, and conſiſts of three *humours*, the *aqueous*, *cryſtalline*, and *vitreous*. Parallel rays are by theſe converged to a focus at the bottom of a perfect eye, and an image is painted of the object they proceed from, upon the *retina*. But if the eye be too convex, the rays will meet before they reach the retina: if too flat, they will tend to a point beyond the retina.

The firſt is remedied by concave glaſſes, or by holding the object very near the eye; the laſt by convex glaſſes.

If an object be placed in the focus of a convex glaſs, the rays, after refraction, will proceed parallel among themſelves; and an eye placed on the other ſide, will have a diſtinct view of the ſaid object, which will alſo appear to be magnified: for a perfect eye cannot ſee any thing diſtinctly nearer than 8 inches. Therefore if the focal diſtance of the glaſs be half an inch, the apparent diameter will be increaſed 16 times; if $\frac{1}{4}$ of an inch, 32 times. Hence they become of uſe as magnifiers, or *ſingle microſcopes*, for viewing ſmall objects.

A *compound microſcope* has a ſmall object glaſs fixed in one end of a tube, and an eye glaſs in the other end: the object is placed upon a ſtage a little further from the glaſs, than the focus of parallel rays. By this glaſs an image is formed of the object in the tube, and is as much magnified in length as the diſtance between the image and glaſs, is greater than the diſtance between the object and glaſs; which ſuppoſe 8 times; then if the eye glaſs be one inch focal diſtance, the image by it will be magnified 8 times alſo, and by both glaſſes 64 times in length. In moſt microſcopes, a third glaſs is added to increaſe the field of view.

The magnifying power of the *ſolar microſcope* is computed by dividing the breadth of the room by the diſtance between the object and glaſs. Suppoſe the firſt be 6 yards, and the laſt half an inch, then will the object be magnified 423 times in length, 186,624, in ſurface, and 80,621,568 times in ſolidity.

The *camera obſcura* is made of various forms and ſizes. It is intended to exhibit a painting of ſuch objects as are before it. A ſingle convex glaſs forms this painting, and the box is always ſo contrived, that the glaſs can be moved to its proper focus, from the ſcreen on which it is formed.

A *perſpective glaſs* has in one end a convex object glaſs, and in the other a concave eye glaſs, which is placed at its focal diſtance within the focus of the object glaſs. Let the focal diſtance of the object glaſs be 6 inches, and that of the eye glaſs 1 inch; then the diſtance between them will be 5 inches. The magnifying power of this inſtrument is computed by dividing the focal diſtance of the object glaſs by that of the eye glaſs.

The *aſtronomical teleſcope* has in one end an object glaſs, by which the rays are converged to a focus, where an image is formed of the object they proceed from. This image is viewed by an eye glaſs, placed at its focal diſtance from it, in the other end of the tube; and is as much magnified as the focal diſtance of the object glaſs is greater than the focal diſtance of the eye glaſs. All objects ſeen through this teleſcope appear inverted.

The common *terreſtrial teleſcope* has three eye glaſſes of the ſame focal diſtance, by which the image is viewed erect. Its magnifying power is computed the ſame way as the laſt.

It is an imperfection in refracting teleſcopes, that heterogeneal light is not refracted to the ſame point in the axis of the object glaſs; otherwiſe the focal diſtance of the eye glaſs might be very ſmall, and the magnifying power very great.

This imperfection is in part remedied in *Doland's patent teleſcope*, which is a very great improvement of the common refracting one.

The *reflecting teleſcope* is a wide tube, open at one end, and in the other is fixed a concave mirrour with a hole in the middle. Rays of light falling upon this, are reflected back and croſs in its focus: after which, in a diverging ſtate, they fall upon a ſmall concave, placed nearly at its focal diſtance from the focus of the great mirrour, by which they are reflected back through the hole in the great mirrour, and fall upon a convex glaſs, by which they are converged to a focus, and form an image, which is viewed by an eye glaſs in the end of the tube. This teleſcope magnifies 8 or 10 times as much as a refracting teleſcope of the ſame length.

THE *magic lanthorn* has a large convex glaſs in one ſide, and a candle being placed in its focus, the rays, after refraction, proceed parallel to each other, and illuminate a tranſparent painting. At a diſtance, in the end of a tube, is fixed another convex glaſs, by which the rays are converged to a focus, and form an image of the painting, vaſtly magnified, upon a white ſheet on the ſide of a dark room.

LECTURE IX.

Of Mechanics.

THIS ſcience treats of motion, explains the laws obſerved by moving bodies, and teaches how to compute the force of the mechanical powers, whether ſingle or combined in machines. By this ſcience the utmoſt improvement is made of every natural power, and the various elements made ſubſervient to the purpoſes of man.

THERE are three laws which are obſerved by all moving bodies whatever.

THE firſt is, *That every body endeavours to continue in a ſtate of reſt, or moving uniformly in a right line.*

THE ſecond is, *That the change of motion is always proportioned to the generating force impreſſed, and is always made according to the right line in which that force is impreſſed.*

THE third is, *That action and reaction are equal, and in contrary directions.*

Of the deſcent of bodies in non-reſiſting mediums.

A BODY left to itſelf, begins to deſcend, or is carried towards the centre of the Earth, by the power of gravity. This power acts conſtantly upon all bodies in proportion to their quantities of matter: hence, bodies containing unequal quantities of matter, will deſcend with the ſame velocity. A body, in one ſecond of time, will deſcend through a ſpace of 16.13 feet; at the end of this time, were the attraction to ceaſe, it has acquired a velocity which would carry it with an uniform motion over a ſpace of 32.26 feet in the next ſecond: but the attraction of gravitation acting conſtantly upon it, its motion continues to be accelerated, and it is carried over a ſpace of 48.39 feet, or three times as far as in the firſt ſecond. From hence it appears, that falling bodies will be conſtantly accelerated; that the ſpaces fallen through will be as the ſquares of the times, or as the ſquares of the velocities, viz., if a body in a certain time falls through 16 feet, in twice that time it will fall through 4 times 16 feet, in three times the time, through 9 times 16 feet, &c. the *momentum* of a falling body is always as the time or velocity. When the velocity is the ſame, it is as the quantity of matter, and is found by multiplying the quantity of matter by the velocity.

Of bodies deſcending down inclined planes.

As the length of the plane, is to the height thereof, ſo is the ſpace paſſed over by a falling body, to the ſpace deſcended through on the ſurface of the plane in the ſame time. And as bodies are carried down the inclined plane by the power of gravity, it is evident they will be equally accelerated, as well as thoſe which fall in perpendicular directions; that is, whatever ſpace they paſs over in one ſecond of time, they will in two ſeconds paſs over four times that ſpace, &c. and the velocity at the loweſt point will be equal to that which would be acquired by a perpendicular deſcent through the altitude of the plane.

While the altitude of the plane remains the ſame, the velocity at the loweſt point will always be equal, whatever the length be: ſo that if a body deſcends down a number of contiguous planes, or down a curve, the velocity at the bottom, as alſo the *momentum*, will ſtill be equal. The times of deſcent down planes of the ſame altitude, but of different lengths, will be directly as the lengths.

From the above we may infer, that whether a body deſcends through the diameter of a circle, or through any chord of the ſame circle, the deſcent will be performed in the ſame time; and the velocity at the loweſt point, will be equal to that which would be acquired by falling through the perpendicular height of the chord.

If, while a body deſcends down one chord, another falls through the diameter of the circle, then while it would aſcend up the oppoſite chord, which would be in the ſame time, the falling body would paſs over four times the diameter of the circle. The times of deſcent in arches, are to thoſe in their reſpective chords, as 1 to .7854. Therefore the length of a pendulum to vibrate ſeconds will be found by the following proceſs, to be 39.2 inches; for, as 1 (the ſquare of 1 ſecond) is to 16.12 feet, ſo is $\frac{1}{4}$ (the ſquare of $\frac{1}{2}$ a ſecond) to 4.03 feet, the diameter of a circle, in whoſe chord a body would deſcend and aſcend in a ſecond of time. Its radius is 2.01 feet; and as the deſcent in the arch, is to the deſcent in the chord, as 1 to .7854, it will be, As the ſquare of .7854, is to the ſquare of 1, ſo is 2.01 feet, to 3.26 feet, = 39.2 inches. The lengths of pendulums are in the ſame ratio, as the ſquares of the times in which they vibrate. Therefore to find the length of a pendulum to vibrate half ſeconds, ſay, As 1 (the ſquare of 1 ſecond) is to $\frac{1}{4}$ (the ſquare of $\frac{1}{2}$ a ſecond) ſo is 39.2 inches, to 9.8 inches, the length required, &c.

Bodies thrown in horizontal, oblique, or upright directions, are called *projectiles*. Every projectile is acted upon by two forces, the *impetus* or *projectile* force, and the *power of gravity*. By the firſt, it paſſes over equal ſpaces in equal times; but by the ſecond, it falls through ſpaces which are as the ſquares of the times. Every projectile, therefore, moves in a curve, except they be thrown upright, in which caſe, to appearance, they will move nearly in a ſtreight line.

Every body revolving round a centre, is alſo acted upon by two forces, the *centrifugal* and *centripetal.* The centrifugal ariſes from the firſt impulſe, and tends to carry the body off from the centre: but by the centripetal force it is conſtantly drawn towards the centre. If theſe forces have a certain ratio to each other, the body is kept revolving round a centre in a circle or ellipſis.

In revolving bodies we muſt obſerve the quantity of matter, the diſtance from the centre, and the periodical time, or time in which the body makes one revolution round the centre.

Two equal bodies revolving round a centre at the ſame diſtance, and in the ſame time, will have equal centrifugal forces.

If the diſtances and periodical times be equal, the centrifugal forces will be directly as the quantities of matter.

If the periodical times and quantities of matter be equal, the centrifugal forces will be in the ſame ratio as the diſtances.

If the periodical times be equal, and the diſtances be reciprocally as the quantities of matter, the centrifugal forces will alſo be equal.

When the diſtances and quantities of matter are equal, the centrifugal forces are directly as the ſquares of the velocities, or reciprocally as the ſquares of the periodical times.

THESE laws are all demonſtrated in the lectures by the *central machine.*

THE centre of magnitude is a point which is equally diſtant from every part of the ſurface. The centre of motion is that point which remains at reſt, while all the outward parts of the body revolve round it. The centre of gravity is a point in every body, which, if ſuſtained, the whole body remains at reſt: in uniform and homogeneal bodies it is in the middle of a right line drawn between oppoſite angles; in a circle it is in the centre; in a triangle it is in a line drawn from an angle to the middle of the oppoſite ſide, one third of the length of that line from the ſide. From a knowledge of this centre, we account for the phænomenon of the rolling cone, which ſeems to roll upwards between two inclined wires, *as ſhewn in the lecture.* Alſo for the cylinder, which rolls up an inclined plane, while the centre of gravity deſcends. From hence we alſo ſee the reaſon why ſome bodies ſtand more firmly on their baſes than others; for while the perpendicular line which paſſes through this centre falls within the baſe of the body, it cannot fall, &c.

If a number of bodies be connected together by a line, there will be a common centre of gravity among them, which, if ſupported, they all remain at reſt.

There are generally reckoned ſix mechanical powers.

1. *The Lever,*

Which is of three ſorts. The firſt has the *weight* at one end, the *power* at the other, and the *fulcrum* or *prop* between them. The ſecond ſort has the *fulcrum* at one end, the *power* at the other, and the *weight* between them. The third ſort has the *fulcrum* at one end, the *weight* at the other, and the *power* between them.

In order to obtain an equilibrium in the lever, the power muſt always be to the weight, as the diſtance of the weight is to the diſtance of the power from the fulcrum: for then the product of the power, multiplied by its diſtance, will be *equal* to the product of the weight, multiplied by its diſtance from the fulcrum, which is always the caſe when they balance each other. For bodies of unequal magnitude can only balance each other when their *momentums* are equal, and this can only happen when their velocities are reciprocally as their quantities of matter. * The power of every kind of lever is computed by the ſame rules.

2. *The Wheel and Axis.*

In this machine the power is applied to the circumference of the wheel, and the weight to the circumference of the axis. Its force is computed by dividing the diameter of the wheel by the diameter of the axis.

3. *The Pulley.*

A single pulley, if fixed, does not increaſe the power: for it is evident the weight and power will paſs over equal ſpaces in the ſame time. But in a combination, where one part is fixed, and the other moveable, the power will be to the weight, as unity to the number of ropes which come to the lower or moveable block: or however they be combined, the power will be to the weight, as the velocity of the weight is to the velocity of the power.

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* Let w = the weight
p = the power

$$\left.\begin{array}{l} d = \text{diſtance of the weight} \\ n = \text{diſtance of the power} \end{array}\right\} \text{from the fulcrum}$$

Then as $p : w :: d : \frac{dw}{p}, = n$, hence if any three of theſe be given, the fourth may be found; for we have

$$n = \frac{dw}{p}, \quad p = \frac{dw}{n}, \quad w = \frac{pn}{d}, \quad d = \frac{pn}{w}$$

4. *The Inclined Plane.*

The inclined plane makes an oblique angle with the horizon. The length of the plane is the diſtance, upon its ſurface, between the loweſt point and the higheſt. The altitude of the plane is the perpendicular height from the horizontal line which touches its loweſt point. If a body is to be ſuſtained upon the inclined plane, the power will be to the weight, as the height is to the length of the plane; or, as the ſine of the angle of elevation is to the radius.

5. *The Wedge.*

A line drawn from the middle of the head to the edge, is called the axis, or length of the wedge.

When the direction of the reſiſtance is perpendicular to the axis, the power will be to the reſiſtance, as the breadth of the head is to the length. For the axis is the ſpace paſſed over by the power, and the thickneſs of the head, that paſſed over by the reſiſtance.

6. *The Screw.*

The force of the ſcrew is computed by comparing the velocity of the weight with the velocity of the power; for ſuppoſe the diſtance of the threads be one inch, and the length of the lever to which the power is applied be 3 feet, then, in one revolution of the ſcrew, the weight will riſe one inch, and the power will move through a ſpace of 226.28 inches. From whence it appears, that the power by ſuch a ſcrew would be increaſed above 200 times.

All theſe computations would anſwer very exactly were there no friction; but a very conſiderable part of the force is deſtroyed by friction; ſo that in loaded machines, engines, &c. we may deduct in ſome $\frac{1}{6}$, in others $\frac{1}{5}$, $\frac{1}{4}$, or $\frac{1}{3}$ part of the whole effect.

All machines, however complicated, are compoſed of the ſimple powers, differently combined together, and the force or effect of the whole is found by computing the force of every ſeparate power, and multiplying the products together; as for *example*, in the common *crane*, ſuppoſe the length of the handle be 18 inches, and the diameter of the nut 4 inches; if 10 ſtone be applied to the handle, it will balance 90 at the circumference of the nut, for it is 9 times as far from the centre. Let the diameter of the great wheel be 2 feet, and the diameter of the axis 4 inches, then, by this, the power will be increaſed 6 times, which multiplied by the laſt, will give 54; ſo that if 10 ſtone be applied to the handle, it will balance 10 times 54, or 540, at the axis.

LECTURE X.

Of Geography.

THAT the Earth is of a globular form is evident from the ſhadow caſt upon the Moon in a lunar eclipſe, by obſerving ſhips at ſea, and by ſailing quite round it. Yet it has been found, by meaſuring a degree of latitude at the equinoctial, polar circle, and ſeveral other parts, that the Earth is not a perfect globe, but an oblate ſpheroid, being a little flatted at the poles. This alſo agrees with the theory of revolving bodies, for were the Earth fluid, as it probably might in part, at the beginning, the parts under the equinoctial would be thrown further from the centre, by the centrifugal force, which is there computed to be $\frac{1}{289}$ part of gravity. That the Earth is not a perfect globe, is alſo proved by the vibrating of pendulums: for it is found, that a pendulum to vibrate ſeconds, muſt be longer at the polar circles than at the equator; and that the difference is more than would be produced by the centrifugal force.

HOWEVER, when the various continents, iſlands, ſeas, gulphs, rivers, &c. are delineated upon the ſurface of a globe, it may be conſidered as a juſt repreſentation of the habitable world.

THE circles of the ſphere are the *equinoctial, ecliptic, meridian, horizon, colures, tropics,* and *polar circles.*

THE EQUATOR, or EQUINOCTIAL LINE, is a great circle which runs eaſt and weſt quite round the globe, being every where at an equal diſtance from the poles, or axis, round which the globe turns.

THE ECLIPTIC is that great circle, in which the Sun always appears to move. It cuts the equinoctial in two oppoſite points, called *Aries* and *Libra*, and makes an angle with it of 23½°.

MERIDIANS are great circles which paſs through the poles of the world, through the zenith and nadir, and cut the equinoctial line at right angles.

THE HORIZON is a great circle which bounds the ſpectator's ſight in the heavens, and is every where equally diſtant from the place where we ſtand. On the artificial globe it is repreſented by a broad wooden circle.

THE COLURES are two meridians, one of which paſſes through the beginning of *Aries* and *Libra*, and is called the equinoctial colure; and the other through the beginning of *Cancer* and *Capricornus*. and is called the ſolſtitial colure.

The leſſer circles are the two *tropics*, and the two *polar circles*. The *tropic of Cancer* is $23\frac{1}{2}°$ to the north, and the *tropic of Capricorn* $23\frac{1}{2}°$ to the ſouth of the equinoctial. One bounds the Sun's declination on the north, and the other on the ſouth ſide thereof.

The northern *polar circle*, called the *arctic circle*, is $66\frac{1}{2}°$ north of the equator: the ſouthern or *antarctic circle* is the ſame diſtance ſouth of the equator.

There are two *frigid zones*; one is ſurrounded by the arctic circle, and the other by the antarctic circle.

There are alſo two *temperate zones*; one lies between the tropic of Cancer and the arctic circle; the other between the tropic of Capricorn and the antarctic circle. All that ſpace which lies between the two tropics, is called the *torrid* or *burning zone*.

The inhabitants of the torrid zone are called *Amphiſcii*, becauſe at noon they caſt their ſhadows different ways at different ſeaſons of the year.

The inhabitants of the temperate zones are called *Heteroſcii*, becauſe their ſhadows at noon always fall one way.

The inhabitants of the frigid zones are called *Periſcii*,

Periſcii, becauſe in ſummer they caſt their ſhadows quite round them.

THOSE who live under the ſame meridian, but have as many degrees ſouth latitude as we have north, are called *Antiœci* or *Antiſcii*: they have the ſame hour, their days are always the length of our nights, and their ſummer is our winter.

THE *Periœci* lie under the ſame parallel of latitude, but differ 180° in longitude: their days and nights are always the ſame length of ours; their ſeaſons are alſo the ſame, but they have the contrary hour, or noon, when we have midnight.

THE *Antipodes* have as many degrees ſouth latitude as we have north, and alſo differ 180° in longitude, and conſequently are directly under our feet; their day is always the length of our night, their ſummer is our winter, and they have noon when we have midnight.

A CLIMATE is ſuch a ſpace of the globe, that in ſummer, the longeſt day on the north ſide (if in north latitude) exceeds the longeſt day on the ſouth ſide, by the ſpace of half an hour. There are 24 climates on each ſide of the equator, between it and the polar circles; and 6 on each ſide between the polar circles and poles, where the length of the days on that ſide of the climate next the pole, exceeds the length on the other ſide by a whole month.

The *globe* is divided into three different *ſpheres.* Thoſe who live under the equinoctial, have a *right ſphere*, and have the poles in the horizon. A *parallel ſphere* has the equator in the horizon, and all the circles of latitude parallel thereto. An *oblique ſphere* has one pole elevated above the horizon, and the other depreſſed below it.

Latitude of a place, is its diſtance north or ſouth, from the equator.

Longitude is the diſtance between the meridians of any two places, and is counted upon the equator.

The Zenith is that point in the heavens which is directly over our heads.

The Nadir is that which is diametrically oppoſite, or right under our feet.

A Continent is the largeſt diviſion of land, comprehending various *countries*, *empires*, and *kingdoms*, not ſeparated by water.

An Island is a tract of land entirely ſurrounded by water.

A **Peninsula** is a part of land, all ſurrounded by water, except a narrow neck, called an

Isthmus, by which it is joined to the continent.

A **Promontory** is a mountainous part of land, ſtanding far into the ſea.

The Ocean is the largeſt collection of waters; it lies between and environs the continents.

A **Sea** is a ſmaller part of the ocean which goes between the continents.

A **Gulph** is a part of the ſea every where encompaſſed with land, except one ſmall part, called a

Strait, which is that narrow paſſage by which it is joined to the adjacent ſea.

A **Lake** is a large quantity of ſtagnant water, entirely ſurrounded with land.

The whole ſurface of the globe contains near 200 millions of ſquare miles: the inhabited part 39 millions; the ſea and unknown parts 161 millions. From whence it appears, that there is more than 4 times as much water as land upon the ſurface of the globe.

LECTURES

LECTURES XI. & XII.

Of Aſtronomy.

ASTRONOMY is that ſcience which diſcovers to us the true motions, magnitudes, diſtances, eclipſes, and other appearances of the heavenly bodies. In the *Solar Syſtem*, which is compoſed of the Sun, 6 primary, and 10 ſecondary planets, beſides comets, the Sun is placed in the centre, and the planets revolve round him from weſt to eaſt, at different diſtances, and in different periods; as in the following Table.

	Diſtances in Miles.		Periods.			Diurnal Revolutions.		Diameter in Miles.	Velocity per Hour in Miles.
			Y.	D.	H.	D.	H.		
Mercury	36	Millions.		87	23	unknown		3,000	109,700
Venus	68			224	17	24	8	9,000	80,300
Earth	95		1	0	0	1	0	7,970	68,200
Mars	145		1	321	17	1	0$\frac{3}{4}$	5,150	55,000
Jupiter	494		11	315	0	0	10	94,000	29,000
Saturn	907		29	167	0	unknown		78,000	22,000

The ſpace in which the planets move, ſeems to be void of all matter which can afford reſiſtance;

for doubtleſs they continue to move with the ſame velocity which they had at the beginning, which, according to the laws of nature, they could not do if they were reſiſted: for the planets are conſtantly acted upon, or kept moving round the Sun by two powers; one is the centripetal force, or attraction of the Sun; by this they are conſtantly acted upon, and drawn towards the Sun's centre: the other is the centrifugal or projectile force, by which they endeavour to fly off in tangents to their orbits. The projectile force, which remains the ſame, was communicated by the creator at the beginning: and as the attraction of the Sun at every planet is different, ſo is the centrifugal force; for it is neceſſary that they have a certain ratio to each other, in order to keep the planets revolving in orbits nearly circular. Comets move round the Sun in orbits vaſtly excentric; and, like the planets, always deſcribe equal areas in equal times; for as they approach the Sun, their velocity increaſes. The diameter of the Sun is 893,760 miles; it turns round its own axis, which makes an angle of 8 degrees with the ecliptic, in ſomething leſs than 26 days.

JUPITER has four moons, whoſe orbits lie nearly in the plane of the ecliptic. They revolve round him from weſt to eaſt: the firſt at the diſtance of 5.6 ſemidiameters in 1 day, 18 hours, and 27 minutes;

nutes; the ſecond at the diſtance of 9 ſemidiameters in 3 days, 13 hours, and 13 minutes; the third at the diſtance of 14.2 ſemidiameters, in 7 days, 3 hours, and 49 minutes; the fourth at the diſtance of 25.3 ſemidiameters, in 16 days, 16 hours, and 32 minutes. This planet is alſo ſurrounded with cloudy dark ſtreaks, commonly called his belts, but what they are is at preſent unknown.

Saturn is attended with five ſatellites or moons: the firſt, at the diſtance of 2 ſemidiameters, revolves in 1 day, 21 hours, and 18 minutes; the ſecond, at the diſtance of 2.4 ſemidiameters, revolves in 2 days, 17 hours, and 41 minutes; the third, at the diſtance of 3.6 ſemidiameters, revolves in 4 days, 12 hours, and 25 minutes; the fourth, at the diſtance of 8 ſemidiameters, revolves in 15 days, 22 hours, and 41 minutes; the fifth, at the diſtance of 23.3 ſemidiameters, in 70 days, 22 hours, and 4 minutes. Beſides theſe moons Saturn is alſo incompaſſed with an amazing phænomenon, called his *ring*, the diameter of which is computed at 120,000 miles. This ring is inclined to the plane of the ecliptic, about 31 degrees; its nodes are in 19 degrees and 45 minutes of Virgo and Piſces. When Saturn is in thoſe ſigns, the plane of the ring paſſes through the Earth, it will therefore be inviſible, or appear like a ſtreight line upon the diſk of the planet. But when Saturn is in Gemini and Sagitarius, the ring will be moſt open, and in the beſt poſition to be viewed.

The *Georgium Sidus*, or new planet, diſcovered by the indefatigable *Herſchel*, it is preſumed will be ſomething more than 80 years in making one revolution: it is at the diſtance of 1800,000,000 miles from the Sun. Mr. Herſchel has alſo diſcovered two moons which attend it. It now appears in the conſtellation of Gemini. In January, 1790, viewed from the Earth, it will be about 8 degrees in Leo, with 39 minutes north latitude. Its mean motion is little more than one degree in three months.

There have been two other hypotheſes invented to account for the celeſtial appearances, called the *Ptolemaic* and *Tychonic ſyſtems. But in the lectures they are ſhewn by the planetarium, to be inſufficient to account for the phænomena, and therefore exploded; and the Copernican proved by unanſwerable arguments and demonſtrations, to be the true ſyſtem of the world.*

As all the planets are retained in their orbits by the attraction of the Sun, ſo is the Moon by the attraction of the Earth: the Earth and Moon mutually attract each other, in proportion to their quantities of matter. By this power they are connected, and between them there is a common centre of gravity,[*] at the diſtance of 1218 miles from the Earth's ſurface. It is this centre that deſcribes the great orbit round the Sun, and not the Earth itſelf, for both the Earth and Moon revolve round this centre once a month. Hence the Earth will be about 11,000 miles nearer the Sun when the Moon is full, than when ſhe is changing.

THE EARTH in one day turns round its own axis, and in one year is carried round the Sun, with its axis inclined to the plane in which it moves, making an angle therewith of 66½ degrees, and always retaining its paralleliſm, by which means the poles alternately incline towards the Sun. When the Earth is in Libra, the Sun appears in the equator, and the circle of illumination paſſes through the poles of the world: the days and nights are now of an equal length on every part of the globe. But while the Earth moves from Libra to Capricornus, the north pole will conſtantly turn towards the Sun, and the ſouth pole from it; during which ſpace, the days in northern latitude are conſtantly increaſing, and the nights decreaſing. When the Earth comes to the beginning of Capricornus, we have the longeſt day and ſhorteſt night, and the Sun appears in the oppoſite ſign Cancer. At this time, the whole northern frigid zone is illuminated, and the ſouthern obſcured in darkneſs. The circle which divides between the light and dark hemiſphere, juſt touches the polar circles, ſo that at every place, except the equinox and poles, the days and nights are of unequal lengths. After the Earth has paſſed the beginning of Capricornus, the north pole begins to turn from the Sun, and the ſouth pole towards it. The days in northern latitude, again begin to ſhorten, and in ſouthern latitude to lengthen. When the Earth comes to the beginning of Aries, the poles are equally diſtant from the Sun: the circle of illumination again divides all the parallels into equal parts, and the days and nights are every where of an equal length. As the Earth moves forward from Aries to Cancer, the days, in northern latitudes, will continue to ſhorten, and in ſouthern latitudes to lengthen. When the Sun appears in the beginning of Capricornus, which happens when the Earth arrives at the beginning of Cancer, the days in northern latitudes are of the leaſt length, and the nights of the greateſt; at which time we have the middle of winter. The whole northern frigid zone is now obſcured in darkneſs, and the ſouthern frigid zone all illuminated. When the Earth has paſſed this point, the north pole will gradually turn towards the Sun, and the ſouth pole from it. The days conſtantly increaſe, and the nights contract, while the Earth moves through that half of the ecliptic. When the Earth comes to the firſt point of Aries, it has made one revolution round the Sun. The days and nights, as at firſt, are now equal all over the Earth. Whence the cauſe of the different ſeaſons, and different lengths of days and nights is evident. *Explained by the Orrery.*

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[*] The diſtance of this centre is found as follows.

Let e = the quantity of matter in the Earth = 45.
m = the quantity of matter in the Moon = 1.
a = the diſtance between the Earth and Moon = 240,000.
x = the diſtance between the centre of the Earth and the centre of gravity.

Then (per mechanics) we ſhall have $ex = ma - mx$; and $x = \frac{ma}{e+m}$, viz. *if the quantity of matter in the Moon be multiplied by the diſtance between the Earth and Moon, and that product divided by the ſum of the quantities in the Earth and Moon, the quotient will be the diſtance from the Earth's centre,* = 5,218 miles.

The 12 ſigns of the Ecliptic.

Northern Signs.		Southern Signs,	
♈	*Aries,*	♎	*Libra,*
♉	*Taurus,*	♏	*Scorpio,*
♊	*Gemini,*	♐	*Sagitarius,*
♋	*Cancer,*	♑	*Capricornus,*
♌	*Leo,*	♒	*Aquarius,*
♍	*Virgo,*	♓	*Piſces.*

THE orbit of the Moon makes an angle of 5 degrees and 20 minutes with the plane of the ecliptic, and interſects it in two oppoſite points, called nodes, one of which is called the Dragon's-head, and the other the Dragon's-tail. When the Moon is in theſe points or nodes, ſhe has no latitude; but when ſhe is in any other part of her orbit, ſhe is ſaid to have north or ſouth latitude, according as ſhe is north or ſouth of the ecliptic. In the *orrery* the Moon is carried round by a ſyderial plate, on which are engraved the ſigns of the ecliptic. On another plate is alſo engraved her age, the diſtance from her nodes, and latitude; by which, when the orrery is rectified, her age, place in the ecliptic, diſtance from her nodes, and latitude, are, for any day, pointed out. The nodes of the Moon do not remain fixed in the ſame part of the ecliptic, but have a retrograde motion, and make one revolution in 18¾ years. This motion of the nodes is the cauſe of various phænomena: it is owing to this, that the Moon, once in 19 years, goes further, both north and ſouth, than at any other time, and that the eclipſes always happen at different ſeaſons of the year, &c.

The Moon, like all the planets in the ſyſtem, is an opaque or dark body, and ſhines upon the Earth by reflection from the Sun: therefore, as the Moon is conſtantly moving round the Earth, it is evident, that when ſhe is between the Earth and Sun, her dark ſide will be turned towards the Earth, and ſhe will be invisible. As ſhe moves from conjunction, her illuminated ſide will gradually turn towards the Earth, till ſhe be oppoſite to the Sun, when ſhe will appear full. After which time, ſhe will again conſtantly decreaſe, till the conjunction or change. *Shewn by the Orrery.*

While the Moon makes one revolution round the Earth, ſhe alſo turns once round her axis, and of conſequence ſtill keeps the ſame ſide towards the Earth; ſo that a ſpectator in the Moon would always ſee the Earth, which is a *moon*, to the Moon, in the ſame part of the heavens, and it would appear, when full, about 13 times larger in ſurface than the full moon appears to us. As the Moon only turns once round her axis in a lunation, one lunar day and night will be the length of 29½ of ours. The Moon, in the ſpace of 27⅓ days, moves through all the ſigns of the ecliptic, or quite round the Earth: this is called the ſyderial day. The reaſon that ſhe is not again in conjunction with the Sun, is owing to the Earth's progreſſive motion in its orbit, by which the Sun appears to have moved through near a whole ſign to the eaſt, ſo that the Moon will yet require about 2⅙ days to come up with the Sun; which ſpace of time is called the difference between her periodical and ſynodical revolutions, or between her ſolar and ſyderial day.

The Moon, ſome days before and after the change, appears cuſped; and the poſition of theſe cuſps, at different times of the year, is very different; but always the ſame at the ſame ſeaſon. *Shewn by the Globe.*

THE different angles, which different parts of the ecliptic make with the horizon, when riſing, is the cauſe of that phænomenon we call the Harveſt Moon: Virgo and Libra make the greateſt angle; Piſces and Aries, the leaſt: ſo that in a given time, a greater length of the ecliptic riſes in theſe ſigns than in any other: and did the Moon move in the ecliptic, ſhe would riſe about 26 minutes later every night for 6 nights together. But as the orbit of the Moon does not lie in the plane of the ecliptic, ſhe will ſometimes riſe with leſs difference of time, and ſometimes with more. For when her north node is in Aries, and her ſouth node in Libra, her orbit will make the leaſt angle with the horizon, at the riſing of Aries, than can be. In this latitude, it will not be more than $7\frac{1}{6}$ degrees, and ſhe will riſe, for 6 nights, within one hour and 35 minutes of the ſame time; or ſhe will be about $\frac{1}{4}$ of an hour later of riſing every night; but ſhe will differ $1\frac{1}{4}$ hour every morning in her ſetting.

WHEN the ſouth node is in Aries, and the north node in Libra, the Harveſt Moon will be leaſt advantageous: ſhe will differ near twice as much in her riſing, as ſhe did in the laſt poſition of her nodes; the reaſon whereof appears plain by the *Orrery.*

The Moon riſes with the ſame difference of time once in every lunation, as ſhe does in harveſt; but as this does not happen at the full moon, at any other time of the year it is not much noticed. The north node will not be in the beginning of Aries before the year 1801, when we ſhall have the Harveſt Moons to the greateſt advantage.

At the equinoctial they have no Harveſt Moon; for an equal quantity of the ecliptic always riſes in the ſame time. But as the latitude increaſes, the angle, which the ecliptic makes with the horizon, at the beginning of Aries, gradually decreaſes, till we come to the polar circle, where there is no eaſtern angle, and of conſequence one half of the ecliptic riſes at the ſame time. In this latitude, the Moon does not differ more than 1 hour in her riſing, for 15 days, but is 23 hours later in her ſetting.

An eclipſe of the Sun is cauſed by the Moon coming between the Sun and the Earth; and is either total or partial. In like manner, an eclipſe of the Moon is cauſed by the Earth intervening, or coming between the Moon and the Sun: ſo that the Moon loſes her light in paſſing through the Earth's ſhadow. If the orbit of the Moon was in the ſame plane with the orbit of the Earth, there would be an eclipſe of the Sun at every new moon, and an eclipſe of the Moon at every full. But this is prevented by the latitude of the Moon, except ſhe be within 12 degrees, 2 minutes, and 9 ſeconds of the node at the time of the full, or within 18 degrees and 20 minutes at the time of the change; which diſtances are called the limits. The nodes, which almoſt retain their parallelifm, only come in a line with the Sun twice in a year, and therefore there can only be two ecliptic ſeaſons in one year. The limits are not always the ſame, owing to the different diſtances of the Sun and Moon from the Earth, at different times. When the ſolar limit is leaſt, the Sun will paſs over it in 28 days; and when greateſt, in 32 days: in which time, the Moon may come twice in conjunction with the Sun, and ſo cauſe two ſmall eclipſes. However, in every ſolar limit, there is one eclipſe very certain. When the lunar limit is leaſt, the Earth's ſhadow will paſs over it in 19 days; and when greateſt, in about 24 days. So that the Moon cannot be eclipſed more than once; but may, and often does paſs the limit without ſuffering an eclipſe.

The Earth has a third motion, whereby the pole of the world is conſtantly moving round the pole of the ecliptic. By this motion the equinoxes fall 50 ſeconds ſooner every year than the year before; and the fixed ſtars, by it, appear to move 1 degree eaſtward in 72 years. Since obſervations have been made upon the ſtars, they have moved through almoſt a whole ſign; for the conſtellation which was once in Aries, is now in Taurus; and the conſtellation of Taurus is now in Gemini. By this motion the ſeaſons are conſtantly moving backward, or in *antecedentia*, and would make one revolution in 25,920 years. If the world continues 12,960 years, the longeſt day, in northern latitude, will be when the Sun enters Capricorn, and the ſhorteſt, when he enters Cancer.

All the ſtars which are viſible in the heavens, except five planets, are called *fixed ſtars*, and ſeem to be fixed in the ſame part of abſolute ſpace. The motions which they ſeem to have, are cauſed by the motion of the Earth. For if the Earth turns round its axis in 24 hours from weſt to eaſt, they muſt appear to move from eaſt to weſt. The fixed ſtars are at immenſe diſtances from the Earth or Sun. Was a body to fly from the Sun with a velocity of 8 miles per minute (which is about as ſwift as a cannon ball) it would arrive at the orbit of Mercury in 8¾ years; at Venus in 16½ years; at the Earth in 22¾ years; at Mars in 34½ years; at Jupiter in 117¾ years; at Saturn in 215¾ years; but it is ſuppoſed, it would not reach the neareſt of the fixed ſtars in leſs than 700,000 years. However, their diſtance is utterly unknown, being immeaſurable and inconceivable. It is ſuppoſed, that the different degrees of brightneſs or ſplendour which we obſerve amongſt the ſtars, is owing to their different diſtances from us, and not to any difference in their magnitude; for it is moſt likely, that they are equally diſtant from each other, as they are from the Sun. They ſhine by their own native or unborrowed light, and are innumerable, for by a teleſcope, thouſands may be ſeen, which are inviſible to the naked eye. We cannot, therefore, ſuppoſe that theſe unſeen ſtars were placed in the heavens, in order to ſupply the inhabitants of the Earth with a faint light in the night, for which purpoſe ſome think the reſt of the ſtars were made: neither can we ſuppoſe that they were made to declare to the Earth the greatneſs and power of the creator, becauſe very few of the race of mankind have ſeen them, or heard of their exiſtence: nor can we think that the Almighty has created any thing in vain: but we may reaſonably conclude that they are ſuns, or fountains of light, illuminating ſyſtems of planets, whoſe motions are controlled by their attractive power; and that the ſtars, which are inviſible to the inhabitants of the Earth, proclaim the glory and wiſdom of the Deity to other intelligent beings, dwelling in worlds placed far beyond the utmoſt bounds of our ſight. This hypotheſis diſplays the greatneſs and dominion of the divine being. This confines not the creation within the narrow bounds of the ſphere of fixed ſtars, but ſuppoſes it extended through the regions of immeaſurable ſpace.

This wide machine, the univerſe regard,
With how much ſkill is each apartment rear'd!
The Sun, a globe of fire, a glowing maſs,
Hotter than melting flint or fluid glaſs,
Of this our ſyſtem holds the middle place.
Mercury, the neareſt to the central Sun,
Does in an oval orbit circling run;
But rarely is the object of our ſight,
In ſolar glory ſunk and more prevailing light.
Venus the next, whoſe lovely beams adorn
As well the dewy eve as opening morn,
Does her fair orb in beauteous order turn.
The Globe Terrestrial next with ſlanting poles
And all its pond'rous load unwearied rolls.
Mars next in order, further from the Sun,
Does in a more extenſive orbit run.
Then we behold bright planetary Jove,
Sublime in ſpace, through his wide province move;
Four ſecond planets his dominion own,
And round him turn, as round the Earth the Moon.
Saturn, revolving in the higheſt ſphere,
Is by five moons attended through his year:
The vaſt dimenſion of his path is found
Five thouſand million Engliſh miles around.

Yet is this mighty ſyſtem, which contains
So many worlds, ſuch vaſt ætherial plains,

But one of thouſands, which compoſe the whole,
Perhaps as glorious, and of worlds as full.
The ſtars which grace the high expanſion, bright
By their own beams and unprecarious light;
Tho' ſome near neighbours ſeem, and ſome diſplay
United luſtre in the milky way,
At a vaſt diſtance from each other lie,
Sever'd by ſpacious voids of liquid ſky.
All theſe illuſtrious worlds, and many more,
Which by the tube aſtronomers explore;
And millions which the glaſs can ne'er deſcry,
Loſt in the wilds of vaſt immenſity,
Are *ſuns*, are centres, whoſe ſuperior ſway
Planets of various magnitudes obey.

If we with one clear comprehenſive ſight,
Saw all theſe ſyſtems, all theſe orbs of light;
If we their order and dependence knew,
Had all their motions and their ends in view,
With all the comets which in æther ſtray,
Yet conſtant to their time and to their way;
Would not this view convincing marks impart
Of perfect wiſdom and ſtupendous art?

Blackmore.

BRITISH MUSEUM
30 DEC 65

AN
EXPLANATION
OF
TECHNICAL WORDS, TERMS, &c.
Uſed in the foregoing LECTURES.

A

ACID, ſour, ſharp.
Accumulate, to heap up, to gather together.
Adheſion, a cleaving, or ſticking to.
Alkali, a fixed ſalt, or ſubſtance that will ferment with an acid.
Ambient, encompaſſing.
Analogy, ratio, proportion.
Aperture, an opening, hole, &c.
Aphelion, that point in a planet's orbit which is fartheſt from the Sun.
Apparatus, inſtruments for performing experiments.
Atmoſphere, the air.

C

Capillary tube, a tube with a bore as ſmall as a hair.

Central, of or belonging to a centre.

Circumambient, ſurrounding on all ſides.

Coheſion, ſticking together.

Compreſs, to preſs together.

Concave, hollow.

Concentric, that have the ſame centre.

Condenſe, to make thick or cloſe.

Conjunction, a meeting of two planets, &c. in the ſame degree.

Contact, touching each other.

Convex, round, protuberant, like the ſurface of a globe.

Convergent, tending to, or meeting in one point.

Counterpoiſe, to balance.

Cuſps, the horns of the Moon, &c.

D

Deſcent, a going down.

Dichotomiſed, diſſected, divided into two equal parts.

Diſk, the viſible ſurface of a planet, &c.

Diurnal, daily, belonging to the day.

Divergent, ſpreading, or ſeparating.

E

Ebullition, boiling, &c.

Eccentric, that hath different centres.

Eclipſe, a deprivation of light.

Efferveſcence, waxing or growing hot.

Effluvia, the very ſmall particles emitted from bodies.

Elaſtic, ſpringy.
Ellipſis, an imperfect circle, and oval-like figure.
Emerſion, a riſing out, or appearing again.
Epitome, an abſtract, or ſhortening.
Epocha, or *Æra*, a fixed point of time from whence the ſucceeding years are numbered.
Equilibrium, an even balance.
Evaporate, to exhale, or reſolve into vapours.
Exhauſt, to draw out, or empty.
Expanſion, a ſwell, or increaſe of bulk.
Exploſion, a noiſe, or report.
External, outward.

F

Fibres, ſmall threads, or filaments.
Flaccid, looſe, not tight.
Focus, that point where all the rays of the Sun which fall upon a concave mirrour, or lenſe, are collected.

G

Gibbous, round, convex, or bunched out.

H

Halo, a circle appearing round the Moon, &c.
Hemiſphere, half of a globe or ſphere.
Heterogeneal, of different kinds or ſorts.
Homogeneal, of the ſame ſort.
Horizontal, level, parallel to the horizon.
Hypotheſis, a ſuppoſition, &c.

I

Imbibe, to abſorb, or drink in.
Immerge, to immerſe, or plunge in water.
Immenſe, infinite.
Impetus, a blow, or impulſe.
Incidence, a falling upon.
Inſulated, ſupported by an electric ſubſtance,
Interſtices, a diſtance or ſpace between.
Irradiate, to ſhine upon, or enlighten.

L

Lateral, of or belonging to the ſide.
Lenſe, a glaſs ground convex.
Longitudinal, lengthways.

M

Medium, that peculiar conſtitution of any ſpace or region through which bodies move.
Mephetic, noxious.
Momentum, the whole force with which a moving body ſtrikes againſt another in its way.

N

Nocturnal, of or belonging to the night.
Noxious, poiſonous, deſtructive.
Nubilous, cloudy, gloomy.
Nucleous, the head of a comet, &c.

O

Oleaginous, oily, or full of oil.

Opaque, dark, ſhady.
Orbit, the path of a planet or comet.
Orifice, a hole, aperture, or mouth.

P

Particles, the ſmalleſt parts of matter.
Percuſſion, a ſtriking.
Perihelion, is that point in a planet's orbit which is neareſt to the Sun.
Perforate, to bore, or pierce through.
Phaſes, the different appearances of the Moon, &c.
Phænomenon, ſignifies an appearance, effect, or operation of a natural body.
Preponderate, to outweigh.
Projectile, a body thrown or projected from the Earth.

R

Ratio, reaſon, proportion.
Rarefy, to make thin.
Recipient, a glaſs receiver for the air pump.
Reflection, a beating back.
Refraction, turning aſide, or out of a ſtreight line,
Refrangible, capable of being refracted.
Reſervoir, a place for water.
Retrogradation, a going backward.

S

Saturated, filled.
Sluice, a flood gate, a drain.

Subterraneous, under ground.

Syzygia, the conjunction and oppoſition of a planet with the Sun.

T

Tangent, a ſtreight line juſt touching the circumference of a circle.

Tenſion, a bending, or ſtretching.

Tranſit, a paſſing over, or croſſing.

V

Valve, a kind of lid or cover, letting a fluid paſs one way but not the other.

Velocity, celerity, ſwiftneſs.

Vertex, the top of any thing.

U

Univerſe, the aſſemblage of Heaven and Earth, or of all created beings.

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